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THE EARLY IDENTIFICATION OF ACADEMIC SUPPORT NEEDS
OF FIRST YEAR UNIVERSITY ENGINEERING DRAWING STUDENTS
IN A MULTICULTURAL SOCIETY

A thesis submitted to the
University of Cape Town
in fulfilment of the requirements
for the degree of

MASTER OF PHILOSOPHY

in the Faculty of Education

by

WENDY MILLROY

B. Sc. (Rhodes), B. Sc. (Hons) (Cape Town)

1985

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ACKNOWLEDGEMENTS

My supervisor, Dr K Rochford, for being an excellent mentor and for showing so much patience and understanding.

The following members of staff of the Universities of Cape Town and the Witwatersrand, whose willing support, interest and co-operation was invaluable.

Mr A Sass, Department of Mechanical Engineering, UCT.
Mr I Scott, Director, Academic Support Programme, UCT.
Mr J Volminck, Academic Support Programme, UCT.
Mr J Galvin, Faculty of Engineering, UCT.
Dr C Potter, Undergraduate Cadet Scheme, University of the Witwatersrand.
Mr E van der Merwe, Department of Mechanical Engineering, University of the Witwatersrand.

Mr A Nel, Mathematics Department, Cape Technikon.

Mrs C Elton, who typed the manuscript so cheerfully, promptly and expertly.

The Human Sciences Research Council, for financial support.

My good friends Mr J Taylor, National Institute of Personnel Research, and Mr G Pastoll, Teaching Methods Unit, UCT, for their interest, encouragement and constructive criticism which helped so much in the early stages of the research.

(ii)

Mr T Griffin, Department of Civil Engineering, UCT for the inspiration he gave me by setting such a good example.

My brother, Mr D Millroy, who has exercised a great positive influence on all my education.

-----oOo-----

This work is dedicated to my parents, Mr and Mrs C W Millroy, in appreciation of their financial assistance, enthusiasm and interest.

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LIST OF ABBREVIATIONS

EAD	-	Engineering Drawing and Design Course
ME102	-	Mechanical Engineering Drawing Course 1.
NFER	-	National Foundation for Educational Research (Britain).
UCT	-	University of Cape Town
NPIR	-	National Institute of Personnel Research
ETS	-	Educational Testing Service
DP	-	"Duly Performed" certificate
DET	-	Department of Education and Training - Matriculation Authority for Blacks
DIA	-	Department of Internal Affairs - Matriculation Authority for Coloureds
ED	-	Education Department - Provincial Matriculation Authority for Whites.
GMAT	-	Graduate Management Aptitude Test

INDEX WORDS

Three-dimensional

Spatial visualisation

Spatial ability

Engineering

Engineering drawing

Mechanical drawing instruction

Cultural differences

Cross-cultural

Disadvantaged

Black

THE EARLY IDENTIFICATION OF ACADEMIC SUPPORT NEEDS
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ABSTRACT

Batteries of exercises requiring visualization in three dimensions were administered to more than 900 freshmen engineering students at the University of Cape Town in 1983, 1984 and 1985, and at the Cape Technikon in 1985. They were found to be consistently powerful predictors of performance in the midyear and final first year engineering drawing examinations.

The cultural populations under consideration consisted of students classified by statute as "Black", "White" and "Coloured". By law most pupils in each ethnic group are educated within separate education systems in South Africa. Cultural differences existing between ethnic groups tend to be reinforced by these three different education systems and by socio-economic classes which tend to be distributed along racial lines.

Although individual students with gross spatial disabilities were identified in all three ethnic groups, the cross-cultural study carried out in this investigation illustrates the significant differences in the

mean performances of students emerging from the three different education systems both in the spatial batteries and in the first year engineering drawing course at UCT. These differences are discussed in terms of language problems, educationally disadvantaged backgrounds and cultural differences.

The spatial batteries were found to be the best predictors of engineering drawing examination results at tertiary level irrespective of cultural group, and are proving to be particularly useful for identifying students urgently in need of special academic support in engineering drawing right from the commencement of their course.

CHAPTER ONE

THE ORIGINS AND CONTEXT OF THE RESEARCH

1.1 INTRODUCTION AND STATEMENT OF THE PROBLEM

During recent years lecturers in engineering drawing at several South African universities have become concerned about the obvious difficulties experienced by so many students during their first year mechanical engineering drawing course. Van der Merwe (1983: 1), for example, has remarked:-

"These difficulties seem to relate to a lack of ability to visualise the third dimension in the conventional two-dimensional representation of engineering objects as well as to deficiencies in elementary reasoning. The difficulty with spatial perception has become more apparent as the number of students having disadvantaged backgrounds has increased".

At the University of Cape Town, too, the studies of Rochford (1984) into the attainment of spatial concepts by university science students have attracted the active attention of the Department of Mechanical Engineering.

It has become important and necessary to develop methods for identifying university engineering students needing special attention early enough for remedial work to be effective within the first year, thus reducing failure and repetition of engineering drawing in the following year. It is felt that if the students have not attained a certain level of proficiency in engineering drawing by June, little is to be gained by completing the course and writing the end-of-year examination. Timely identification is, therefore, imperative.

In an investigation into the factors associated with success in an engineering drawing and design course (EAD 1) at the University of the Witwatersrand, Taylor (1980) reported that the ability to comprehend spatial relations varies across a wide spectrum. Spatial ability did not appear to be strongly related to the results of any of the common Matriculation subjects. He found that EAD 1 results could be substantially predicted by using the results of standard pencil and paper tests of spatial ability - the H-test and the BLOX test. This method has been used by Potter and van der Merwe (1984) to identify the most appropriate candidates for their special EAD course described in Chapter Two.

Blade and Watson (1955) found good correlations between the NFER* Spatial Test 1 and the performance in an engineering drawing examination written three years later.

Marsicano (1975) concluded that the traditional combination of high school results and verbal and mathematical scholastic aptitude tests could be improved by including spatial perception and abstract reasoning tests in the battery used to predict academic success in engineering technology at Pennsylvania State University.

In an attempt to predict the academic success of first year engineering students at the University of Durban-Westville (using Matriculation results and several psychometric tests), Behr (1982) found that the Gottschaldt Figures Test showed significant correlations with engineering drawing.

* National Foundation for Educational Research (Britain).

Research conducted at other universities reveals that the disturbing number of failures occurring in the engineering course by students who cope with all subjects except those involving aspects of engineering drawing and design is not a phenomenon peculiar to the University of Cape Town (Taylor, 1980; van der Merwe, 1983).

Furthermore, worldwide research points to the fact that spatial ability can be taught, and that spatial ability improves with experience and with exposure to conducive environments. Remedial academic support has shown successful results. (Potter and van der Merwe, 1984)

The research undertaken by Blade and Watson (1955), Dawson (1967), and Behr (1982) confirms that spatial ability can improve with instruction at university level.

The University of the Witwatersrand, working in conjunction with the National Institute of Personnel Research (Taylor, 1980), conducted research which culminated in the development of a special course in Engineering Analysis and Design (EAD) which was given to students identified as requiring academic support in 1981. Whereas in previous years 50% to 60% of first year engineering students passed EAD at the University of the Witwatersrand, in 1981 the pass rate rose to 90%. (Potter and van der Merwe, 1984).

Many cross-cultural studies of spatial ability have been carried out during the past forty years. One of the earliest studies in South Africa was done by Hudson (1960; 1962) who concluded from his tests of depth perception carried out on White, Coloured, Black and Indian samples that cultural experience and not educational standard was the determining factor in dimensional perception of pictures. Criticism has been levelled at Hudson over the years for the way in which he conducted these early experiments, but evidence emerging from subsequent research has highlighted particular difficulties with spatial visualisation encountered by students from non-Western cultures, or from non-industrialised nations.

Sinha and Shukla (1974 : 435) observed that "research trends point to the importance of the child's environment which provides the experiential basis for the acquisition and proper development of various cognitive skills". More specifically, language and socio-economic level have a great impact on the development of spatial ability.

The African languages spoken by Black students at home and in which they receive instruction for the first half of their primary schooling, do not always provide an adequate base for describing the spatial environment scientifically. Neither the technical concepts nor the technical vocabulary is available in the mother-tongue. The fact that Black students are taught in English later in their school careers and may appear to be fluent in this language, does not imply that they have the depth of comprehension necessary to successfully cope with scientific and engineering studies (Kemp, 1983).

Low socio-economic levels may result in various kinds of deprivation. In 1974, Sinha and Shukla showed that an impoverished environment with minimal opportunity for interaction with adults and the outside world, very few toys or picture books and monotonous and homogeneous surroundings were associated with a strong detrimental effect on the development of pictorial depth perception of children aged four to six-and-a-half years.

Well-illustrated childrens' books, technical toys such as Meccano, Lego, model-building, chess and jigsaw puzzles - seen as significant in the development of good spatial ability (Kemp, 1983) - are rarely available in impoverished homes.

Black engineering students represent sectors of the South African community where the home environment is disadvantaged and where educational facilities are limited (van der Merwe 1983), thus few of these students experience exposure to commerce and industry and therefore acquire neither the technical vocabulary nor an awareness of the relevance of their studies which is vital for success (Kemp, 1983).

In the light of the above, the necessity for an investigation at the University of Cape Town of academic support needs for engineering drawing students along cultural lines is self-evident. The provision of effective remedial courses and assistance for first year students whose preparation for university is incomplete because of an

inadequate schooling or other reasons of a "cultural" nature, may be extremely important. At the same time it is realised that the problem may occur among individual students of all cultures, but that some groups as a whole may be more significantly disadvantaged than others.

1.2 PURPOSE OF THE STUDY

It appears that many students, for a variety of reasons, have difficulty visualizing in three dimensions. Many fail the ME102 engineering drawing examination at the University of Cape Town, apparently unable to acquire fully the insight and spatial ability required to represent concepts visually in diagrams and drawings during the normal presentation of the first year drawing course.

This investigation aims to answer the following questions:

1. Can most potential failures of engineering drawing at the University of Cape Town (UCT) be identified at the commencement of their courses - in time for remedial academic support measures to be effective?
2. What is the optimum design of a diagnostic test used to measure important aspects of spatial ability which are relevant to first year engineering drawing students?
3. What is the optimum combination of measures (spatial and non-spatial) which may be used, to predict performance in the engineering drawing examination at UCT?

4. Is there a significant difference in the performance of students originating in the different official education systems provided by law for each cultural group in South Africa, with respect to
 - (a) Spatial battery results
 - (b) June (midyear) engineering drawing results
 - (c) November (year-end) engineering drawing results?
 5. Will the Spatial battery emerge as the best predictor of performance in engineering drawing at UCT irrespective of cultural group?
 6. Do the Shell Bursary* students perform significantly better in the Spatial battery and in the engineering drawing course than their peers of the same cultural group?
-

* The Shell Bursary Scheme was started in 1980. Each year approximately 20 Non-white scholars are chosen from promising Matriculation candidates to be sponsored for a post-matric year at a private school, e.g. Michaelhouse or Diocesan College, followed by sponsorship for the 4-year Engineering degree at UCT. The selections are made by a committee on the basis of an interview with the scholar, his academic record and 3 NIPR tests including a Reasoning Ability Test and the BLOX Spatial Test.

7. Is there a significant difference in the performance in engineering drawing of students writing English as a first or as a second language at Matriculation level? (English taken as a second language at school implies that English is not the mother-tongue).
8. Will the results obtained in the Spatial battery by (a) UCT first year engineering degree students, and (b) Cape Technikon first year engineering diploma students, show significant differences?

1.3 THE IMPORTANCE OF THE PROBLEM

There are conflicting views in the industry as to whether or not there is a shortage of professional engineers in South Africa at present. In a report published by the Federation of Societies of Professional Engineers in 1984, critical shortages of professional manpower in civil and electrical engineering disciplines are described. However, R. Heydenrych, President of the South African Institution of Civil Engineers refutes the contention that there is a shortage of civil engineers in the country. In an interview with South African Construction World in May, 1985, he identified that the poor quality of recruits entering the profession is a worrying problem.

There is a high demand in this country for people with engineering skills (whether professional engineers or technicians) and a competence in engineering drawing is essential in all technical areas.

Over the past five years at the University of Cape Town, an annual average of 11,2% of first year engineering students have failed to meet the minimum requirements for entry into second year and have had to leave the engineering faculty. Over the same period, an average of 12,8% of first year engineering students have failed the final mechanical engineering drawing (ME102) examination. If there had been some way of identifying the academic support needs of these students and if remedial classes had been formally presented, the wastage rates may have been lower. Bridging the gap between school and university seems to be a particular problem for many first year engineering students.

The importance of cross-cultural research with respect to education in South Africa is clear. Our multicultural society with different languages, education systems and socio-economic classes emphatically entrenching the differences between the various population groups, faces an urgent need for reform, and equality of educational provision is one of the most emotive and essential issues to deal with.

Traditionally the engineering field has been dominated by the White male. Attempts have been made, for example, by the Anglo American Corporation and by Shell Oil Company, to create opportunities for members of other race groups to enter the profession.

There has also been evidence of a great effort being made in the U.S.A. to attract Black students into engineering and engineering

technology programs and to provide the academic support needed. (Kiehl, 1971; Edmunds, 1974; Wilburn, 1974; Greene, 1979; Williams, 1981; Garay, 1983; Project P.A.C.E. Final Report, 1983-84).

Van der Merwe (1983) and Potter et al (1984) highlight some of the special academic support requirements of Black engineering students at the University of the Witwatersrand. Many of these students are drawn from disadvantaged sectors of the South African community. Homes are impoverished and the education system is limited by many poorly qualified teachers and inadequate government funding. For example, in the Department of Education and Training, 15% of the teachers in Black schools have no qualifications, and 65% have only a standard eight school leaving certificate plus two years at training college (Corporate Responsibility : Management, April 1985, pgs 36 - 38).

Research carried out throughout the world indicates that there are cultural differences in visual perception and pictorial conventions. (Poole, 1969; Coppen, 1970; Nicholson, 1974; Bermingham, 1976; Alonge, 1977; Mitchelmore, 1980). These perceptual differences have educational implications as pointed out by Hudson (1960, 1962, 1967); Berry (1966); Coppen (1970); Macrae (1974); Nicholson (1974) and Bishop (1979).

Deprivation stemming from socio-economic factors may have a detrimental influence on the acquisition of spatial abilities (Sinha and Shukla, 1974).

There is also evidence that language poses a problem. Black scholars in South Africa are taught in English by teachers who are themselves using a second language. Kemp (1983) notes that in the early years of the Wits-Anglo cadet scheme, one of the most important and difficult challenges was the development of competence in technical vocabulary and verbal comprehension by the students.

The number of Black Matriculated scholars is expected to exceed the number of White Matriculated scholars by the 1990's. If the present circumstances continue, universities must cope with increasing numbers of disadvantaged students whose home and education backgrounds have not adequately prepared them for the standard of work required from a first year student.

The question of the identification of students with special academic support needs and the design of effective ways of providing such support at university level will become increasingly important in the future, and may even differ uniquely from one university and technikon to another. It is in this context that the present investigation should be viewed.

1.4 HYPOTHESES

The hypotheses tested in this investigation are as follows:-

1. That achievement in the mid-year (June) and final (November) engineering drawing examinations (ME102) is significantly related to total scores obtained in pencil and paper tests of spatial ability given on or before the commencement of the programme of lectures.
2. That the spatial battery scores contribute more significantly to the variance in the engineering drawing examination marks than the Matriculation mathematics results, the Matriculation aggregate, and the Spargo physical science test, i.e. that the spatial batteries will be the single most powerful predictors of performance in engineering drawing.
3. That the spatial batteries are the single most powerful predictors of performance in engineering drawing at UCT, irrespective of the cultural group of the sample.
4. That there is a significant difference in the performance of students originating in the different education systems provided for each cultural group, with respect to:
 - (a) Spatial battery scores
 - (b) June (mid-year) engineering drawing results, and
 - (c) November (year-end) engineering drawing results.
5. That the Shell Bursary students perform significantly better than their peers of the same cultural group in both the Spatial battery and the engineering drawing course.

6. That those students taking English as a first language at Matriculation level perform significantly better at engineering drawing than those who take English as a second language.
7. That there will be no significant difference between the performance of the UCT first year engineering students and the Cape Technikon first year engineering diploma students in the Problem-solving/Spatial test administered to both groups prior to the commencement of their programmes of lectures.

1.5 THE SETTING FOR THE INVESTIGATION

POPULATIONS 1, 2 and 3

Studies were carried out on three populations of first-year engineering drawing students at the University of Cape Town.

Population 1 (N = 278) in 1983

Population 2 (N = 249) in 1984

Population 3 (N = 214) in 1985

The tests were administered at the commencement of engineering drawing laboratory sessions in March 1983, and during Freshers' week in February 1984 and 1985 - i.e. before any lectures began.

POPULATION 4 (N = 178) in 1985 at the Technikon

In January 1985, during orientation week, the same battery used at UCT was given to all first year engineering diploma students at the Cape Technikon.

POPULATION 5 (N = 7) in 1984 at UCT

During the months of August and September 1984, 7 of the students who failed the Spatial battery in March, but who passed the June ME102 examination unexpectedly with first or upper-second class honours were re-tested and interviewed.

1.6 DEFINITION OF TERMS

Spatial Ability

For the purpose of this investigation, spatial ability is defined as the ability to perceive, retain and recognise (or reproduce) three-dimensional representations of objects in their correct proportions when they are rotated in space, translated, juxta-positioned, projected, sectioned, re-assembled, inverted, re-orientated or verbally described.

Spatial orientation measures usually require the subject to rotate mentally a figure in two- or three-dimensional space.

Spatial visualisation measures generally require the subject to mentally restructure as well as rotate a figure in space.

Definition of groups used in cross-cultural study

The student population at UCT comprises members of the race groups classified "Black", "Coloured", "White", and "Asian".

Each race group has its own Matriculation education authority and for the purposes of the cross-cultural study, the groups will be referred to as follows:-

The matriculation authority for Black students is the Department of Education and Training. This group of students will be referred to as "DET students".

The Matriculation authority for Coloured students is the Department of Internal Affairs. This group will be referred to as "DIA students".

The Matriculation authorities for White students are the Education Departments in each province. This group will be referred to as "ED students".

1.7 SUMMARY OF CHAPTER

In summary, the aim of this work is to explore the possibility of providing a reliable way of identifying students whose spatial ability is weak and who would benefit from special academic support in Mechanical engineering drawing, a subject taken by all first year engineering students at the University of Cape Town.

Special problems of inadequate preparation at school and the socio--economic and language problems faced by Black students in particular have been mentioned and will be described in more detail in Chapter Two.

CHAPTER TWO

REVIEW OF RELATED LITERATURE

The survey of background literature has been divided into five sections:

2.1 The spatial factor and its components

2.2 Engineering drawing and the spatial factor

2.2.1 Problem solving and Engineering Drawing

2.3 Attitudes and problems of first year engineering students at a multicultural South African University

2.4 The cultural and language aspects of spatial ability, under two sub-headings

2.4.1 Cross-cultural studies

2.4.2 The disadvantaged child

2.5 Summary of the Chapter, and Implications.

2.1 THE SPATIAL FACTOR AND ITS COMPONENTS

Until the late 1940's the mental endowment of children and adults was usually measured by psychological tests yielding a single index of intelligence such as the mental age or intelligence quotient.

With a refinement in understanding of the nature and measurement of intelligence has come the recognition of distinct ability factors. More recently, spatial and perceptual reasoning abilities have been separated out from other components of intelligence.

In an attempt to amalgamate much of the extensive literature on the component factors of intelligence, Ekstrom, French and Harman (1976) of the Educational Testing Service (ETS) produced a "Kit of Factor-Referenced Cognitive Tests". This kit consists of 72 tests which load on 23 factors.

Of the 23 factors isolated in the ETS Kit, seven seem to be related to spatial and perceptual abilities. These are:

1. Flexibility of closure
2. Speed of closure
3. Visual memory
4. Perceptual speed
5. Spatial orientation
6. Spatial scanning
7. Visualization.

These are important in that they offer guidance for the selection and inclusion of items in spatial diagnostic batteries for use with engineering students.

2.2 ENGINEERING DRAWING AND THE SPATIAL FACTOR

Blade and Watson (1955) administered two tests of spatial ability to a group of 90 students entering college. The tests were then readministered after the freshman year. They found that among engineering students there were significant differences in spatial test results between the students with the highest grades and students with the lowest grades at the end of the freshman year. Comparing the pre- (upon entry) and post- (after freshman year) spatial test results they report that engineering students showed significantly greater gains than non-engineering students. This was tentatively attributed to a spatial training effect associated with engineering studies. Low scores on the spatial visualisation test did not necessarily indicate lack of aptitude, but merely lack of related experience.

In a study of 11 - 13 year-old pupils admitted to the Technical School in Middlesborough in 1950 and 1951, Smith (1960) found that NFER Spatial Test 1 scores correlated 0,62 with performance in an engineering drawing examination written three years later, and that Moray House Space Test 1 scores correlated 0,41 and 0,30 with performance in engineering drawing examinations taken five years later.

Marsicano (1975) evaluated tests which can be used for predicting academic success in engineering technology at Pennsylvania State University. He concluded that the traditional combination of high school results and verbal and mathematical scholastic aptitude tests can be improved by including spatial perception and abstract reasoning tests in the predictive battery.

Bermingham (1976) undertook an investigation into cultural variation in spatial and mechanical reasoning in first year B Sc (Hons) engineering students during a ten-year period at an English college of Technology. There appeared to be a marked difference in spatial ability - defined as the ability to visualise concrete objects, and to manipulate those visualisations - between students originating from Britain, and those originating from the South East Asian countries. Although it has been well established that there is no evidence of correlation between spatial ability and general intellectual capacity, it was clear that weakness in the former was a severe handicap in studying engineering subjects. (Further references to cross-cultural studies of spatial ability in general are made in section 2.4.1 below).

In an investigation into the results of a first course in engineering drawing at the University of the Witwatersrand, Taylor (1980) of the National Institute of Personnel Research used stepwise multiple regression equations to establish that the best combinations of predictors in his study consisted of three tests: the DRAT, the BLOX

and the H test. The Deductive Reasoning Ability Test (DRAT) is a non-spatial test of logic and inference, but the BLOX test is spatial and consists of items which require the respondent to study a particular configuration of cubes, and to identify the same configuration of cubes seen from a different view. In the H test, which is also spatial, each question consists of a geometric figure which has to be imagined as an object that can be bent or rolled into a 3-D model.

Taylor (1983) also initiated a study in order to assist those interested in the accurate identification of potential engineering technicians from the Black population group in South Africa. The best single predictor for Pre-Tech drawing was the BLOX test.

In their Draft Report on the Special EAD course, Potter and van der Merwe (1982) described an intervention in engineering education at the University of the Witwatersrand, prompted by the results of the NIPR's research carried out by Taylor (1980) described above. It was thought that the low levels of spatial perceptual skills in students identified as having weaknesses in engineering drawing may be only part of wider conceptual and linguistic gaps, particularly in students entering university from the Black education system (Department of Education and Training), due to a lack of exposure to a Western technological background.

It was decided that the overall aim of any special academic support given should be to develop proficiency in engineering design, rather than merely in engineering drawing. The special Engineering Analysis and Design course would aim to develop the skill of abstract manipulation rather than the skill of operating at a concrete level, and would therefore concentrate on problem-solving activities.

Analysis of the data showed that while the performance of White students on the special EAD course improved relative to the performance of two matched White student samples in the Mainstream EAD course, the performance of Black students on the special EAD course did not improve relative to their Black Mainstream EAD counterparts.

However, the performance of Black students who had undertaken post-matriculation pre-university technical education (e.g. the Anglo American Cadet Scheme or the Johannesburg Chamber of Industries Scholarship Scheme) was significantly better than that of the other Black first-year students in EAD 1 as well as in all other first year engineering courses, except for Physics. It must be remembered however, that these students went through rigorous selection programmes before being awarded scholarships.

Although the effect of the special academic support EAD course was difficult to evaluate, it is likely that the course contributed to raising the pass rate of EAD 1 at the University of the Witwatersrand.

In an attempt to predict the academic success of first year engineering students at the University of Durban-Westville (using Matriculation results and several psychometric tests) Behr (1982) found that the Gottschaldt Figures Test showed a significant correlation with engineering drawing. Retesting the same students at the end of the first year showed a significant improvement in their performance. She concluded that visual perception is amenable to training and that special methods should be introduced to develop this ability both at school level and during the first year at university.

Potter, van der Merwe and Kemp (1983) outlined procedures used for identifying "at risk" students and described the remedial techniques developed in the first year Engineering Analysis and Design (EAD) course, a subject failed by 31% of the total of first year Engineering intake during the years 1976 - 1980 at the University of the Witwatersrand. 7,25% of the student intake dropped out from first year engineering during this period.

Engineering components (e.g. parts from a motor car) were used as the main apparatus from which students learned to draw in three dimensions instead of from pictorial exercises traditionally used. Apparatus such as plasticine, fold-out models, 3-D perspex and stereoscopic viewers, add-on transparencies, and multifaceted mirrors were used where appropriate.

Pilot work on the development of these remedial materials was commenced in 1980 with students in the Undergraduate Cadet Scheme.

Failure rates in EAD of first year engineering students have dropped since the introduction of the remedial methods. For the periods 1981 - 1983, the average final EAD examination failure rate was 10,5% (compared to 31% during 1976 - 1980) but the student dropout rate was 16,8%. (i.e. more than double)

Potter and van der Merwe (1984) further discussed the Special EAD course developed at the University of the Witwatersrand. The BLOX test and the H-test were thought to be particularly reliable predictors of engineering drawing and were given to all first year students. A student identified as doing well in most subjects, but poorly in EAD and having weaknesses in spatial perception shown by the BLOX and the H-test, and having average or above average mental ability (on mental alertness test) was thought to be an ideal remedial candidate for the Special EAD Course.

Conclusions

From this overview of recent studies on the relationship between performance in engineering drawing and spatial ability, it may be concluded (by way of summary) that:

1. Selected pencil and paper tests of spatial ability are reliable predictors of performance in engineering drawing and may be used as a guide to identifying those students in need of special remedial help in this area.

2. Spatial ability skills can, in general, be trained; and special teaching methods can be employed to develop this ability to a certain extent during the course of the academic year.
3. In South Africa, students entering universities from the Black education system (Department of Education and Training) have, for various reasons, more difficulties with engineering drawing concepts than any other group. ✓

2.2.1 Problem Solving and Engineering Drawing

Van der Merwe (1983) described visits undertaken with lecturer C. Potter to three South African Universities to investigate what was being taught to first year engineering students, what methods were employed to teach and what problems were being encountered, particularly with students requiring academic support. They shared experiences in an attempt to generate fresh ideas on improving teaching methods.

Much groundwork had been carried out by the University of the Witwatersrand, in conjunction with Anglo American, in the development of three-dimensional perceptual engineering drawing abilities, and in involving the students in projects and site visits. It had become clear that problem-solving is the focal point of the engineering curriculum in second year and beyond, and that a development of problem solving techniques in particular was required.

Kemp (1983) also emphasised the importance of problem-solving. He suggested that engineering education at tertiary level consists of two main parts: firstly, the understanding of the basic principles of science and technology and, secondly, the development of a competence in problem-solving.

Problem-solving involves asking pertinent questions, sensing what is important, making realistic assumptions, relating to other problems and thinking in terms of analogies. These abilities require an appreciation of and interest in the subject, competence in expressing the relevant contextualised language and a clear, visual perception of the behaviour.

"Good problem-solvers in engineering have been identified as people with the confidence and motivation to persist with the problem. They frequently develop a visual image of the model they are using and its response by the use of sketches. They appreciate the language of the subject and can describe the process in their own words". (Kemp, 1983 : 257).

Many scholars, particularly (but not exclusively) from the Black community, experienced difficulties in using contextualised language and representing concepts visually in diagrams and drawings and resorted to superficial, rote learning. Their problems were acute, probably because of their disadvantaged school and home background and second language education.

Conclusion

The findings uncovered in this section of the literature review may be summarized as follows:

1. Good problem-solving ability appears to play a major role in the success of an engineering student, especially after the first year of study.
2. Successful problem-solving in engineering requires, in addition to a thorough basic understanding of the scientific and technical principles and the ability to express ideas clearly using relevant contextualised language, the ability to form a visual image of the problem and to translate that into diagrams and sketches.
3. Many students, particularly those from the Black community, experience difficulties with the solving of problems.

2.3 ATTITUDES AND PROBLEMS OF FIRST YEAR ENGINEERING STUDENTS AT A MULTICULTURAL SOUTH AFRICAN UNIVERSITY

In a very detailed piece of research on study habits and attitudes of engineering students conducted at the University of the Witwatersrand by Potter et al (1984) the following aspects were thought to be the most relevant to this research. These problems relate particularly to first year engineering students.

- 2.3.1 The gap between school and university appeared to be a particular problem for all first year engineering students.

There was an obvious lack of career counselling which led to poor orientation to engineering as a career.

- 2.3.2 Students found it difficult to cope with the heavy workload and rapid pace of instruction.

- 2.3.3 The ability to interact and communicate with others appeared to be important, not only for the adequate development of problem solving abilities, but also to obtain help with course work.

- 2.3.4 Black students had particular problems, such as poor preparation at school, dependence on rote learning, language problems, and conceptual difficulties. Language, especially difficulty with technical terms, hampered the understanding of the context of lectures and the taking of appropriate notes (especially when dictated), causing the Black student to be reticent in asking questions even when it was clear that he or she did not understand.

- 2.3.5 Difficulties in visualising in three dimensions in the EAD course were seen as problematic for Black students.

2.3.6. Black students appeared to operate from a position of isolation compared to the informal student network operating among their White counterparts, and did not have access to the support systems such as consultation with peers, family, students in higher years of study and graduate students used by most White students.

2.3.7 Not being resident on campus, as a result of discriminating legislation, was seen as a crucial factor counting against success for Black students. Transport and financial factors were additional hurdles.

2.4 CULTURAL AND LINGUISTIC ASPECTS OF SPATIAL ABILITY

A pertinent introduction to the impact that culture and language appear to have on spatial ability may be a quotation from Sinha and Shukla (1974 : 434)

"Man's dependence upon his environment for a major part of his sensory input and its impact on his development have been topics of interest to psychologists and educators for decades".

"Research trends point to the importance of the child's environment which provides the experiential basis for the acquisition and proper development of various cognitive skills.

The first trend is the recently developed interest among contemporary psychologists toward the study of cognitive growth of disadvantaged children.

The second trend is represented by the cross-cultural studies of various cognitive processes revealing the influence of culture and ecology".

2.4.1 Cross-cultural studies

Hudson (1960; 1962) concluded from his tests in South Africa of pictorial depth perception carried out on White, Coloured, Black and Indian samples that cultural experience and not educational standard was the determining factor in dimensional perception of pictures. Formal education was a contributing factor to the attainment of three-dimensional spatial ability under certain circumstances : results indicated that in the case of the White school sample, depth perception improved with progress through primary school.

However, the Black graduate group did not display better depth perception than the White higher primary group. Some Black graduates reported being able to see pictures in both two and three dimensions when required to perform a three-dimensional perceptual task.

In 1966, du Toit criticized Hudson's work on linguistic grounds, suggesting that pictorial depth perception was not well-developed among Southern Africans because their languages did not offer avenues for this aspect of cognition to develop.

Work done by Dawson (1967) suggested that personality may be associated with the comprehension of pictorial depth cues. Using Hudson's methodology, he found that Africans from tribes

in which there was a high level of maternal strictness (and associated field-dependence) comprehended pictorial depth less often than individuals from tribes with a low level of maternal strictness (and associated field-independence). Dawson reported that he was able to teach individuals to interpret depth cues, but that the field-independent individuals showed most improvement. He suggested that the reason for this was that field-dependent subjects are more conforming and less open to new experiences, making them more resistant to learning new ideas.

By 1970 there was widespread awareness of the difficulties that students in various cultural settings faced in pictorial perception. Sufficient research had been conducted to warrant the Commonwealth Secretariat's commissioning a review by Coppen. It was intended to disseminate the findings of this body of research to those concerned with the production and use of pictorial materials in education, particularly in the developing countries of the Commonwealth.

Deregowski and Byth (1970) tested a group of graduate Whites and uneducated Black Zambians using Hudson's pictures in an apparatus called "Pandora's Box" which can indicate whether "depth" responses are primarily a function of interpretation or of perception. (Interpretative cues are those which require overt learning through exposure to pictorial material and which

lead to responses to pictures indicating such perception of depth. Perceptual cues occur independently of such exposure and result in perception of pictorial depth without any awareness of the interpretative elements which may be involved). Results confirmed the existence of pictorial perception difficulties in the Zambian sample and suggested that these might be due to both interpretative and perceptual difficulties defined above. Whites tended not to display any difficulty in responding three-dimensionally.

Wilson (1972) summarised various research findings concerned with the misunderstandings of drawings which occurred when subjects were from a cultural background different from that of the artist. Reference was made to work in Brazil, Costa Rica, Kenya, Mexico and Thailand. The interpretation of drawings was highly culture-dependent, particularly among those with little formal schooling. There were clear implications for the design of learning materials in science and mathematics.

In 1974, Nicholson's investigations added to the growing evidence that many students in non-Western cultures had considerable difficulty in perceiving spatial relationships in diagrams of structure, an ability of great importance in the learning of chemistry. His subjects were at upper-secondary and undergraduate levels.

Dawson and Young (1974) found with their Hong Kong Chinese subjects that lower socio-economic level, field-dependence, harsher socialisation and more traditional attitudes were, as expected, associated with lower three-dimensional pictorial perception test scores. The more permissive Eskimos showed higher three-dimensional pictorial perception than the Chinese sample. A sample of Chinese three-year-olds who had been exposed to considerable cultural stimuli such as toys, photographs and television programmes in a nursery school, showed some evidence of three-dimensional ability in their responses.

Studies involving children from Ghana and Scotland (McGurk and Jahoda, 1975) supported the view that African children had some difficulty with pictorial depth perception and lag behind European children in this respect. However, the evidence did not support the view that African children were grossly deficient in perceiving pictorial depth. Spatial accuracy of Ghanaian children was shown to improve with age. Criticism was levelled at the "ambiguity" of Hudson's test (1960, 1962) and the fact that fairly complex verbal procedures had been employed, again emphasising the importance of language. In testing the Ghanaian subjects, attempts were made to use the child's own vernacular or some acceptable mixture of languages.

In 1975 studies with African children carried out by Leach showed that instruction in pictorial depth perception consistently resulted in improved performance in tests requiring three-dimensional perception. A striking feature of his findings was the high incidence of pictorial depth perception even among uninstructed children. He also levelled criticism at Hudson's methods. A factor contributing to this positive finding of three-dimensional perception in the African subjects was thought to be that the testers were themselves African and conducted the tests in the home language of the child.

Worsnop (1975) described the development and effectiveness of a remedial teaching strategy for students, particularly those from non-Western cultures, who had difficulty in interpreting framework diagrams correctly.

Ahmad (1978) studied subjects whose mother-tongue was Arabic or English and found that pictures had different effects on subjects from the different language backgrounds. While other cultural variables also played a part, the mother-tongue variable was of primary significance, correlating with the degree of unfamiliarity of the picture to the subject. The more unfamiliar the picture, the more significant was the mother-tongue in emphasising certain features of the picture.

Nicholson, Seddon and Worsnop (1977) undertook a joint University of East Anglia (UEA)/University of Lagos research project concerned with the ability of Nigerian secondary school pupils to perceive depth correctly in chemical diagrams. They designed a remedial teaching program to improve that ability.

In 1977, Ross investigated the remedial effect of a self-instructional program as a follow up to the UEA/University of Lagos project. Different kinds of "prompt" were incorporated into different versions of the program, and the effects compared. All forms were effective in increasing the pupils' ability to interpret three-dimensional diagrams. The audio mode of exposition was the most effective.

Bishop (1979) found that students in Papua New Guinea, even at tertiary level, had great difficulty in three-dimensional visualisation and in the interpretation of diagrams. Amongst other cultural problems, that of language was significant. For some students, English was their fourth language. None of their home languages provided an adequate base for describing the spatial environment scientifically.

Mitchelmore (1980) reported a comparison of spatial and three-dimensional drawing ability between two industrialised countries (USA and UK) and a developing country (Jamaica). The study showed significant differences in performance between the

British, American and Jamaican samples. It was suggested that the observed differences in spatial and drawing ability reflect cross-cultural differences in attitude towards the use of spatial models of thinking, an attitude partly revealed by the degree of geometrical emphasis in the schools' mathematics curriculum.

Dos Santos, Seddon and Jusoh (1981) followed up on Whorf (1956) and Bruner (1973) who argued that a person's understanding of the world is affected fundamentally by the language used to communicate and receive this understanding, and Bridgeman (1958) whose work points particularly to the influence which the grammatical features of a language may have upon the manipulation of ideas. They used this reasoning to test the possible implications of teaching students in a language which is different from their native language.

They investigated the existence of these possible language effects in relation to the spatial tasks contained in the test used by Nicholson and Seddon (1977). They concluded that the differences between Portuguese, Malay and English are not such as to produce different factor patterns.

Conclusions

From this survey of recent relevant cross-cultural studies it appears that visual and verbal competence is essential for success in

engineering studies and is therefore relevant for each student. There are students from every cultural background in Africa and beyond who have academic support needs during their years of engineering study, but it is particularly significant to recognise the difficulties faced by Black scholars in South Africa who wish to pursue these studies.

Black students may appear conversant in English as a result of having been taught in this medium in the latter part of their school careers, but this does not mean that they possess an adequate comprehension to tackle scientific and engineering studies (Kemp, 1983).

The vast majority of teachers in Black schools are themselves using a second language in which they sometimes lack confidence. Many black students display a weakness in expressing themselves using contextualised technical language and vocabulary.

2.4.2 The Disadvantaged Child

Over a period of three years (Western New Mexico University, 1967), a group of 510 rural children participated in a study of visual perceptions, including eye motor co-ordination, discernment of figures in a background pattern, form constancy, position in space, and spatial relations, as measured by the Frostig Visual Perceptions test. Results of testing showed that all rural children scored low in form constancy. Culturally deprived children scored lower in all perceptions, but visual perception handicaps were sometimes as great as eight times that of control group children.

Franklin (1969) used Picture-Object matching tests, Spatial Arrangement tasks and Structured Play situations to compare the performance of disadvantaged and advantaged children on tasks requiring representational thought rather than verbalisation. Scores indicated that the disadvantaged group generally did not perform as well as the advantaged children, although there was much variation among individuals tested.

In 1974 Sinha and Shukla hypothesized that any kind of deprivation (due to social, economic, nutritional and other deficiencies in a child's environment) experienced by the child, especially during the early part of his growth, will have a detrimental influence on the development of skill for pictorial depth perception. An investigation of children from orphanages in India (an impoverished environment with minimal opportunity for interaction with adults and the outside world, very few toys or picture books, monotonous and homogeneous surroundings) showed that deprivation was associated with a strong detrimental effect on the performance of the children aged four to five and five to six-and-a-half years in tests of pictorial depth perception.

In many South African schools the emphasis is on rote learning, often to the detriment of achieving insight and understanding (van den Berg, 1983). Questions and investigation of alternative solutions are not encouraged. The problem may be more serious because of a common cultural belief that it is wrong to question one's elders (Kemp, 1983).

Again, in the context of South Africa, the difficulties facing Black engineering students are emphasised. Such students represent sectors of the South African community where homes are impoverished and where educational facilities are limited (van der Merwe 1983). The disadvantaged home environment (with probable lack of exposure in the formative years to illustrated books, visual games, constructive toys, model-building, jig-saw puzzles) also implies that few of them experience an effective exposure to commerce and industry. Subsequently, these students have not only a limited technical vocabulary in these fields but also a limited awareness of the relevance of their studies (Kemp 1983).

2.5 SUMMARY OF CHAPTER, AND IMPLICATIONS

The main findings uncovered by this literature search may be summarized as follows:

1. It is possible to predict the overall performance of students in engineering drawing early in the year by means of pencil and paper tests of spatial ability, although an optimum combination of predictive tests has still to be determined.
2. Spatial ability improves with training. Special academic support given early enough to students who experience difficulties with engineering drawing can result in an improvement in the pass rate in the engineering drawing examination.

3. The ability to solve problems appears to be essential to success in engineering studies. Successful problem-solving requires, in addition to a thorough basic understanding of scientific and technical principles and the ability to express ideas clearly using relevant contextualised language, the ability to form a visual image of the problem and to translate that into diagrams and sketches.
4. First year engineering students generally experience problems in bridging the gap between school and university.
5. In South Africa, students entering certain universities from the Black Education system (known officially as the Department of Education and Training) have more difficulty with engineering drawing concepts than any other group.
6. The problems experienced by Black students should be seen in the light of the evidence that culture, language, socio-economic level and deprivation have an influence on the development of spatial ability.
7. Language plays an important role in the development of spatial ability - for instance, some languages (e.g. African languages, Papua New Guinean languages) do not have an adequate vocabulary for describing the spatial or technical environment scientifically. On the other hand, it has been shown that the use of the mother-tongue is important in recognising the features of unfamiliar diagrams or pictures.

8. People from non-Western, developing countries generally do not perform as well on tests of spatial and three-dimensional drawing ability as do those from Western, industrialised nations.
9. Personality and child-rearing practices appear to have an influence on the development of spatial ability. A high level of maternal strictness and traditional attitudes are linked to lower spatial ability test scores.
10. The development of the pictorial depth perception skills of children from low socio-economic levels who are deprived of interaction with the outside world and with adults, and who live in monotonous surroundings without the stimulation of toys or picture books, are likely to be retarded.

The implications of these findings for the direction of the present investigation at the University of Cape Town are as follows:

1. It is important to develop a battery of spatial tests which are good predictors of engineering drawing results at this university. The early identification, as far as possible, of all students who have problems with three-dimensional concepts is vital to the provision of effective, adequate academic support.
2. It is relevant in our country's multicultural society, to investigate for teaching purposes the differences in performance in the spatial tests and in engineering drawing by students from

different cultures. In South Africa, the cross-cultural differences which may have been present in any case (caused for example by language differences), are further intensified by the fact that education systems and socio-economic classes are divided up by legislation on the basis of these "cultural groupings" as well. A better understanding of reasons for the poor spatial ability of some students may lead to more appropriate education being offered, both at school and through special interventions in the regular lecture system by the Academic Support Programme recently established at UCT.

3. The present investigation will not only attempt to confirm at UCT the findings of Kemp, van der Merwe, Potter and Taylor at other universities. It will also extend and enlarge on their work in the following ways:

- (a) Three different spatial batteries of varying composition and length have been used during the three years of research described in this thesis. This has given some insight into the design of questions and the setting of time limits to refine and improve the predictive qualities of the battery.
- (b) Care has been taken to determine whether the batteries used in 1983 and 1984 are good predictors for each separate cultural group as well as for the population as a whole. It is important for the batteries to be valid for each cultural group.

CHAPTER THREE

EXPERIMENTAL DESIGN, SAMPLE, CRITERION AND PREDICTORS

In this chapter the setting for the investigation is presented, and the characteristics of the five populations chosen for study are described. The research methods used are identified, and the design, development, refinement and properties of the three different spatial batteries used are described. The statistical methods used to analyse the data are presented.

3.1 THE SETTING FOR THE INVESTIGATION

The investigation was conducted in the engineering faculties at the University of Cape Town and at the Cape Technikon. The University of Cape Town is an English-speaking multi-racial institution of some 11 000 students, of whom approximately 85% are Whites. On average, over the past 5 years, 255 first year students registered for the four-year engineering degree course offered in the various engineering disciplines.

The Cape Technikon is a bilingual institution with a student registration figure of approximately 4 200 (enrolment in the first semester of 1985) of whom about 92% are Whites. Students from Non-white race groups are accepted for certain courses not available at the Peninsula Technikon (the parallel institution provided for Non-whites).

3.2 SELECTION AND CHARACTERISTICS OF THE POPULATIONS

During the years 1983, 1984 and 1985, 919 first year engineering drawing students were included in experimental samples drawn from the engineering faculties of UCT (741 students) and the Cape Technikon (178 students).

Five populations are referred to in this study; three comprise first year engineering degree students from UCT, one is a sample of first year engineering diploma students from the Cape Technikon, and one a group of students who were re-tested and interviewed after failing the spatial battery and later achieving an apparently anomolous first class or upper second class result in the June 1984 ME102 examination.

The characteristics, and cultural breakdowns (where applicable) of the five populations are set out below:

Population 1 (1983)

This consisted of 278 UCT first year engineering drawing students representing Mechanical, Civil, Electrical, Materials and Chemical Engineering departments. These novice students were tested in March 1983 using the UCT spatial battery.

There were 12 female students in the group tested. The population was classified by statute into groups along cultural lines as follows:

25 students classified "Black"
207 students classified "White"
26 students classified "Coloured"
5 students classified "Asian"
15 students unclassified racially.

Two additional subgroups were considered within this analysis, viz:

14 Shell Bursary students (comprising 11 Blacks, 2 Coloureds and 1 Asian student).

12 Non-Shell students (for comparison purposes, all Blacks, since the majority of the Shell scholars in 1983 were Black).

The "Asian" group was not considered in the cross-cultural analysis as the numbers were too small to yield significant results.

Population 2 (1984)

This consisted of 249 UCT first year engineering drawing students representing Mechanical, Civil, Electrical and Chemical Engineering departments who were tested in February 1984 using the Glasgow spatial battery.

35% of the class had received some technical drawing training before entering university. There were 11 female students in the group tested. The population was divided into groups along statutory cultural lines as follows:

22 students classified "Black"

202 students classified "White"

23 students classified "Coloured"

2 students classified "Asian".

Two additional subgroups were considered in this analysis, viz:

14 Shell Bursary students (comprising 8 Blacks and 6 Coloureds).

31 Non-Shell students (for comparison purposes, chosen to comprise 14 Blacks and 17 Coloureds, since the 1984 Shell students groups were almost evenly distributed across these two cultures).

The "Asian" group was not considered in the cross-cultural analysis as the numbers were too small to yield significant results.

Population 3 (1985)

This consisted of 214 UCT first year engineering drawing students representing Mechanical, Civil, Electrical and Chemical Engineering faculties who were tested in February 1985 using the Problem-solving/Spatial battery.

47% of the students had had previous training in technical drawing, usually at school. There were 10 female students in the group tested. Matriculation standards required to qualify for entrance to an engineering department at UCT are at least 60% for Mathematics and Science (Higher Grade).

Population 4 (1985)

This consisted of 178 Technikon first year engineering diploma students representing the Electrical, Mechanical and Civil Engineering faculties. These novice students were tested in January 1985 using the Problem-solving/Spatial battery.

Matriculation standards required to qualify for entrance into an engineering faculty at the Technikon are at least 50% for Mathematics and Science (Standard grade) or at least 40% for Mathematics and Science (Higher Grade).

67% of the students had studied technical drawing at school.

Population 5 (1984 subgroup)

This consisted of 7 UCT first year engineering drawing students who were re-tested and interviewed after failing the Glasgow spatial battery and later achieving first or upper second class passes (i.e. above 70%) in the June 1984 ME102 examinations.

These first year students were re-tested in August and September 1984. They were given the identical Glasgow spatial battery they had written in February 1984.

3.3 SELECTION OF DEPENDENT AND INDEPENDENT VARIABLES

The criterion scores (dependent variables) were the June ME102 engineering drawing examination results at the University of Cape Town in 1983, 1984 and 1985 and the November ME102 results in 1983 and 1984.

The predictors (independent variables) were:

3.3.1 Spatial Battery Scores

- (a) The UCT Spatial Battery was used in 1983 and consisted of 33 test items designed in the Education Department at the University of Cape Town. The UCT Battery had been validated from 1980 to 1982 on 250 university science students (Rochford, 1984).
- (b) The Glasgow Spatial Battery was used in 1984 and consisted of 66 items designed and used for several years in the Chemistry Department at Glasgow University.
- (c) The Problem-solving/Spatial Battery was used in 1985, and consisted of 25 "Problem-solving" items requiring spatial ability, the H-test, plus author-constructed items.

Different forms of spatial tests were used in three consecutive years in order to identify those with the greatest diagnostic and predictive validity for freshman engineering students at a multicultural university.

3.3.2 The Spargo Science Test

A test of basic Matriculation level physical science compiled by Professor P.E. Spargo, Science Education Unit, UCT, consisting of thirty multiple-choice questions selected from past Matriculation examination papers.

3.3.3 The Matriculation Mathematics Results (of 1982, 1983, 1984)

3.3.4 The Matriculation Aggregate (of 1982, 1983, 1984)

Copies of the different experimental spatial batteries and an example of the November ME102 examination are included in APPENDIX 1.

3.4 DESIGN, DEVELOPMENT AND PROPERTIES OF THE SPATIAL BATTERIES

(a) The UCT Spatial Battery

Rochford (1984) devised a spatial battery consisting of four sub-tests, as follows:

RV Rotation, visualisation and juxtaposition of geometric objects in three dimensions.

RC Rotation of cubes in space

SYN Synthesis of sections of common geometric objects

SEC Sectioning of geometric solids

Time limits of 15 minutes were set for (RV + RC) and for (SYN + SEC).

Properties of the UCT spatial battery for different populations are tabulated in Table 3.1 on page 60.

The Cronbach alpha coefficient for the UCT spatial battery was $\alpha = 0,82$ ($N = 100$). Individuals who were at least one standard deviation below average - that is, who scored less than 63% on this battery, were classified as likely remedial candidates. (This cut-off point agrees with the criterion score of 23 out of 36 utilised by Nicholson and Seddon, 1977).

Finally the construct validity of the battery was established by correlating 42 students' scores with scores they obtained in NFER Spatial Test 3. The result obtained was $r = 0,84$. Calculation of the Cronbach alpha reliability co-efficient for NFER Spatial Test 3 yielded $\alpha = 0,97$ ($N = 42$).

(b) The Glasgow Spatial Battery

This test comprised ten sections which covered the content of the four sub-tests described previously in the UCT Spatial Battery. A time limit of one hour was imposed.

Properties of the Glasgow spatial battery for freshman engineering students are set out in Table 3.2 on page 61.

Individuals who scored less than 71% in this battery (i.e. at least one standard deviation below average) were classified as potential remedial subjects.

(c) The Problem-solving/Spatial Battery

Potter and van der Merwe (1984) designed 25 problems to test problem-solving and spatial ability which they used, together with the H-test, as a guide to identifying suitable candidates for their Special EAD course (designed as an academic support tool to assist students having difficulty with engineering drawing).

The Problem-solving/Spatial battery includes these twenty-five problems, the H-test, plus some author-constructed items (composed in consultation with the drawing lecturer).

The battery was strictly timed. At the request of the UCT engineering drawing lecturer (who had written the GMAT test at the UCT Business School and had been impressed by its format) the time limits set were such that even the most able student would be stretched, i.e. nobody was expected to finish each section within the allotted time. The battery was divided into four sections:

Section one - 12 problems - 15 minutes

Section two - 13 problems - 15 minutes

Section three - H test - 5 minutes

Section four - Author constructed section - 5 minutes

Invigilators gave detailed explanations and examples before allowing the students to begin each new section, which was then strictly timed. Questions were all in multiple-choice style and answered on a specially prepared answer sheet.

The following provisional cut-off points were set for each section for possible academic support purposes (at least one standard deviation below average in each case):

Section one: 5 or less out of 12 (40%)

Section two: 2 or less out of 13 (15%)

Sections three

and four: 35 or less out of 90 (39%)

Total score: 43 or less out of 115 (38%)

Properties of the Problem-solving/Spatial battery are tabulated in Table 3.3 on page 62.

3.5 COLLECTION OF THE TEST SCORES

Population 1

For normal teaching purposes the 278 first year engineering drawing students at UCT were divided into two approximately equal groups for a three-hour laboratory session once per week.

During a laboratory session in March 1983 the sub-tests of the UCT battery involving rotation, visualisation and juxtaposition of geometric objects in space were given to the two groups. During the following week, the sub-tests requiring the synthesis of sections of common geometric objects and the sectioning of geometric solids were written. Time limits of 15 minutes were imposed in both cases.

Population 2

During Freshers' week in February 1984, 249 first year engineering drawing students at UCT were tested simultaneously in two large groups. A time limit of one hour was imposed for the Glasgow spatial battery which consisted of ten sub-tests involving the rotation, visualisation and sectioning of geometric objects. The tests were set in multiple choice format. Senior students were available during the test to clarify the wording of questions where necessary.

Population 3

During Freshers' week in February 1985, 214 first year engineering drawing students at UCT were tested simultaneously in three groups. The Problem-solving/Spatial battery consisted of four sections which were strictly timed by the invigilators. Thorough explanations and examples were given by the invigilators before the candidates began each section. In total, 40 minutes were allowed for writing the test, while roughly 15 minutes were devoted to explanation by the invigilators. Senior students were available during the test to assist with queries.

Population 4

178 First year engineering diploma students were tested at the Cape Technikon on two separate days in January 1985. The students were divided into eleven groups, the first group being the only one tested on the first day, and the other ten being tested successively throughout the following day. They received the same Problem-solving/Spatial battery administered to Population 3, under very similar examination conditions.

Population 5

It was decided to re-test and interview those seven students who had failed the Glasgow spatial battery and then achieved first or upper second class passes (i.e. above 70%) in the June 1984 ME102

examination. The students were contacted and assembled in two separate groups during August and September, 1984. The Glasgow spatial battery was re-administered under the same conditions and with the same time limits as previously. The students were then interviewed individually, and their responses recorded.

Blade and Watson (1955) noticed similar strange contradictions in their research. Although their tests of spatial ability correlated well with engineering drawing examination results, there were some students who appeared "almost hopeless" on the spatial test, but who performed excellently at engineering drawing. Others had achieved top scores in the spatial tests and had been only average students in engineering drawing. Illness, change of occupational goal etc, accounted for those with good test scores who did less well than expected. Blade and Watson postulated that only a change or growth in the students' ability as measured by the spatial test could explain the outstanding class work produced by those students whose earlier test scores indicated that they lacked the spatial ability to do so.

The following questions were asked by the interviewer in 1984:

1. Did you find the test easier this time than the first time you wrote it?
2. Did you take the first test seriously?

3. Are you aware of looking at things or seeing things differently now, compared to when you first began engineering drawing lectures?
4. Were you aware of everything "falling into place" one day, or did you begin gradually to understand the new concepts and conventions?
5. Do you enjoy engineering drawing?
6. Have you grown to like/dislike it more as the year has progressed?
7. Did you do any extra work to improve?
8. Do you think that intensive "extra academic support" at the beginning of the course would have assisted you?

3.6 STATISTICAL METHODS USED IN THE ANALYSIS

3.6.1 Treatment of each population as a whole

1. T-tests were carried out to compare different achievements of spatially weak and spatially strong students. The calculations were performed using subsets of those

students for whom complete sets of the relevant data were available (N=246 in 1983; N=232 in 1984; N = 185 in 1985).

2. Correlation analysis was used to detect significant relationships among variables.
3. Multiple regression analysis was used to find the best way of combining the independent variables for predictive purposes. The analysis was carried out on subsets comprising students for whom complete sets of the relevant data were available (N=185 in 1983; N=214 in 1984).

3.6.2 Cross-cultural study (carried out in 1983 and 1984)

As described in Chapter One, Section 1.6, the three cultural groups considered in this study are the "DET" students, "DIA" students and "ED" students.

1. Means were computed for comparison of each cultural group according to:
 - a) Spatial battery scores.
 - b) Spargo physical science test scores.
 - c) Matriculation mathematics result.
 - d) Matriculation aggregate.
 - e) June engineering drawing (ME102) result.
 - f) November engineering drawing (ME102) result.

2. T-tests were carried out to determine significant differences between the means for the above results where the three groups were large enough to test statistically.
3. Correlation analysis was used to detect significant relationships among variables for each cultural group.
4. Regression analyses were carried out for each cultural group to determine whether the spatial battery result is the best predictor of achievement in the ME102 examination.
5. Correlation coefficients were calculated for:
 - a) Matriculation English results (1984) with June ME102 (1984) results.
 - b) Matriculation English results - first language (1984) with June ME102 (1984) results.
 - c) Matriculation English results - second language (1984) with June ME102 (1984) results.
6. Means and standard deviations were calculated, and T-tests carried out to compare achievement in the June and November 1984 ME102 examination by the "English first language group" and the "English second language group".

These statistical tests for significance were adopted since the data obtained with the large populations of students satisfied the criteria of normality and homoskedasticity well within the normal limits of experimental error.

3.6.3 Comparison of the performance of UCT students and Cape Technikon students in the Problem-solving/Spatial battery

Means and standard deviations were calculated, and T-tests carried out to compare achievement of these two groups.

3.6.4 Comparison of the performance of Shell Bursary students and other Non-white students

Since the Shell Bursary groups are too small to test statistically, means and standard deviations have been calculated and tabulated for inspection purposes only.

TABLE 3.1

PROPERTIES OF THE UCT SPATIAL BATTERY FOR DIFFERENT POPULATIONS:

MEANS, RANGES AND STANDARD DEVIATIONS

POPULATIONS	N	UCT SPATIAL BATTERY		
		MEAN	RANGE	SD
1. Anatomy students: midyear failures plus five volunteers	42	63,3%	23%-92%	19,6%
2. Anatomy students: Novices	154	77,6%	32%-100%	15,4%
3. Anatomy students: 19 midyear failing novices plus 8 fail/ repeats	27	64,0%	27%-89%	19,1%
4. Astronomy students: Novices	56	66,9%	21%-96%	19,8%
5. Astronomy: End-of- year students with intact records	25	73,0%	20%-100%	14,9%
6. Engineering drawing: Novices (Population 1)	273	78,4%	0%-100%	15,6%
7. Clinical Remedial Teachers	15	34,5%	15%-84%	14,5%

TABLE 3.2

PROPERTIES OF THE GLASGOW SPATIAL BATTERY

FOR FRESHMAN ENGINEERING STUDENTS:

MEAN, RANGE AND STANDARD DEVIATION

POPULATIONS	N	GLASGOW SPATIAL BATTERY		
		MEAN	RANGE	SD
1. Engineering drawing: Novices (Population 2)	231	82,91%	19,7%-100%	11,52%
2. Engineering drawing: Midyear retesting (Population 5)	7	77,5%	60,6%-92,4%	10,7%

TABLE 3.3

PROPERTIES OF THE PROBLEM-SOLVING/SPATIAL BATTERY

FOR DIFFERENT POPULATIONS:

MEANS, RANGES AND STANDARD DEVIATIONS

	POPULATION 3: N=214 UCT first year engineers			POPULATION 4: N=178 Technikon first year engineers		
	Mean	Range	SD	Mean	Range	SD
Section one: Problems	55,3%	0%-83%	17,6%	49,8%	8%-83%	15,1%
Section two: Problems	29,1%	0%-69%	13,5%	27,3%	0%-69%	13,2%
Section three and four: Spatial	54,1%	8%-88%	15,6%	49,4%	21%-90%	14,8%
Total score: Problem-solving/ Spatial battery	51,4%	9%-82%	13,9%	47,0%	23%-80%	12,7%

CHAPTER FOUR

RESULTS

NOTE Tables 4.1 to 4.32 appear consecutively on pages 86 to 117.

4.1 TREATMENT OF EACH POPULATION AS A WHOLE

4.1.1 The Predictive Utility of the Spatial Batteries

Tables 4.1, 4.2, 4.3, 4.4 and 4.7 reveal clearly the predictive value of the spatial batteries:

(a) Population 1 (N = 278)

The results set out in Table 4.1 show that the 46 students who failed the UCT spatial battery obtained a failing average of 41,1% as a group in June, which was 20% below the average June ME102 result of the next group of students (those classified as spatially "borderline" in March). Of these 46 students, 31 failed engineering drawing in June and 2 were absent.

Table 4.2 reveals that 16 of these 46 students failed again in November, 14 obtained third class passes and 7 were absent or had withdrawn. The 7 absentees all scored less than 40% in the June ME102 examination. Overall, 80%

of the group of students who failed the spatial battery in March had, by November, either failed, "dropped out" or obtained a third class pass.

It is apparent that some improvement did take place during the course of 1983. Whereas 33 of the 46 spatially weak students failed or were absent in June (Table 4.1), by November, only 23 of these students had "dropped out" or failed (Table 4.2). The number of third class passes increased by 10 from June to November.

At the other end of the scale, 85% of those who scored top marks in the UCT spatial battery achieved a first or upper second class pass in the November ME102 examination.

(b) Population 2 (N = 249)

The results recorded in Table 4.3 indicate that 65 students falling into the categories "borderline" and "fail" for the Glasgow spatial battery scored an average of 58% in the June ME102 examination. This was 16% below the June average of the next group (spatially "satisfactory").

20 of these 65 students failed the June ME102 examination, 8 were absent and 16 were refused permission to write the November examination on the grounds of failure in June plus a poor class record (i.e. were refused a "Duly Performed" Certificate referred to locally as a "DP").

By November (Table 4.4), 91% of the 32 students who had failed the Glasgow spatial battery outright in February had either failed, obtained a third class pass, were absent, or had been refused a DP after the June ME102 examination.

It is not clear whether any improvement took place in the case of those 65 students in the "Borderline" and "Fail" groups (see Tables 4.3 and 4.4). In June, 37 students out of the 65 passed the examination. Their results were fairly evenly distributed across "Firsts", "Upper seconds", "Lower seconds", and "Thirds". In November, 35 passed the examination. The majority obtained lower seconds or thirds.

It is interesting to note the change in distribution of results from June to November, e.g. 10 of the spatial "Borderline/Fail" students achieved firsts in the shorter June test, but only one achieved a first in the full-length November final examination. See Table 4.5.

Of those students who scored top marks in the Glasgow battery, 80% achieved firsts or upper seconds in June, and 64% in November.

Seven of the 17 students in the "borderline" or "fail" groups who obtained firsts or upper seconds in the June ME102 examination were retested and interviewed in September 1984.

Only one student's spatial result improved dramatically - from "Borderline" to "Excellent". His November ME102 result was 65%, a drop of 8% compared to his June ME102 result. The mean ME102 result of the class as a whole dropped by 6% from June to November.

The other six students showed only marginal improvements in their spatial scores, two remaining in the "fail" group, one improving to "borderline" and three improving to "satisfactory".

An interesting point to note here is that these students' ME102 results plummeted by an average of 19,8% in November, compared to June. Only one of these students achieved a first class pass in November, three obtained third class passes and two obtained lower seconds. (See Table 4.6).

This may imply that the November examination was much more difficult than the June examination, or that these students failed to consolidate their knowledge after an initial struggle and apparent "solution" of their difficulties shown by a good June result. It should also be noted that the November ME102 results are modified by the examiner while the results of the June test are left unmodified.

Results of the Interviews

Five of the students reported that the Glasgow test was easier at the second attempt (but, strangely enough, the only student who was very positive about this was student F (Table 4.6), the only student whose spatial score did not improve with practice!). The other two could not remember. Three of the students reported that they did not take the first test seriously in February. (However they did not improve appreciably at this "more serious" attempt).

Six students reported being aware of "seeing things differently", and of "being able to perceive depth now". All reported, however, that they struggle with each new section of work, and that things do not come easily to them.

Five students felt that their enjoyment of engineering drawing had increased. Most stated that valuable help from friends plus extra work in revising for the June examination had assisted in their achievement of a high pass mark in June.

Only one student did not think that intensive "extra academic support" at the beginning of the course would have been of assistance.

(c) Population 3 (N = 205)

The results shown in Table 4.7 indicate that the 33 students falling into the category "fail" in the Spatial part of the Problem-solving/Spatial battery obtained an average of 61,5% in the June ME102 examination. This was 9,8% below the June ME102 average of the next group (spatially "borderline").

48% of these students obtained a third class pass, failed, or did not write the June ME102 examination.

Of the 70 students who fell into categories "good" or "excellent" in the spatial battery, 76% obtained a first or an upper second class pass in the June ME102 examination while only 7% failed or were absent.

In conclusion, of the three different predictive spatial batteries employed in February or March of the years 1983 to 1985, the best overall predictor appears to have been the Glasgow spatial battery, and the weakest overall predictor of engineering drawing performance appears to have been the Problem-solving/Spatial battery.

4.1.2 T-Tests

(a) Population 1 (N = 246)

Population 1 may be divided into two groups on the basis of passing or failing the UCT spatial battery. A comparison of both the June 1983 ME102 results and the November 1983 ME102 results of the groups "SPATIAL FAIL" and "SPATIAL PASS" reveals that the two groups achieved significantly different results in engineering drawing in both cases. The relevant data is presented in Table 4.8.

Dividing the population into two groups on the basis of "PASS" or "FAIL" in the June 1983 ME102 examination and "PASS" or "FAIL" in the November 1983 ME102 examination reveals that the two groups achieved significantly different scores in the UCT spatial battery in both cases. (See Tables 4.9 and 4.10.)

(b) Population 2 (N = 232)

Dividing the population into two groups "SPATIAL PASS" and "SPATIAL FAIL" on the basis of performance in the Glasgow spatial battery, and comparing their June and November 1984 ME102 results, reveals that the populations performed significantly differently in engineering drawing in both cases. (See Table 4.8)

Comparing the Glasgow spatial scores of the two groups "JUNE PASS" and "JUNE FAIL" shows that the two groups are again, significantly different. The same result is revealed when the groups "NOVEMBER PASS" and "NOVEMBER FAIL" are analysed. (See Tables 4.9 and 4.10)

(c) Population 3

Dividing the population into two groups on the basis of "passing" or "failing" the total Problem-solving/Spatial battery, and comparing their June 1985 ME102 results, shows that the populations performed significantly differently in engineering drawing. (See Table 4.8). Comparing the Problem-solving/Spatial battery scores of the two groups "JUNE PASS" and "JUNE FAIL" shows that the two groups performed significantly differently. (See Table 4.9)

4.1.3 Correlation Analysis

(a) Population 1

Table 4.11 sets out the correlation coefficients for the 1983 students with complete data (N=185). Only the Matriculation mathematics result was not significantly correlated with engineering drawing. The highest correlation coefficients obtained were those between the UCT spatial battery and the ME102 results.

(b) Population 2

Table 4.12 sets out the correlation coefficients which were found for 1984 students with intact scores. Neither

the November 1983 Matriculation mathematics results, nor the Matriculation aggregate showed significant correlations with the June 1984 ME102 examination result (N = 232). However, significant correlations were shown with the November 1984 ME102 result (N = 216) for all independent variables considered. The highest correlation coefficients calculated were those between the Glasgow spatial battery and the ME102 results.

(c) Population 3

Table 4.13 sets out the correlation coefficients found for 1985 students with intact data. Significant correlations were obtained with the June ME102 result for all independent variables considered. The highest correlation coefficient calculated was that for the total score of the Problem-solving/Spatial battery.

From Tables 4.11, 4.12 and 4.13 it can be seen that the spatial test score correlates most strongly with June and November ME102 results thus HYPOTHESES ONE, TWO AND THREE are fully confirmed.

4.1.4 Regression Analysis

Multiple regressions were carried out to find the best way of predicting June and November ME102 engineering drawing results

using the combined independent variables Spatial score, Matriculation mathematics results, Matriculation aggregate and the Spargo physical science score.

(a) Population 1

The results are recorded in Table 4.14. Only the UCT spatial battery score and the Matriculation aggregate were found to be significant as predictors of June and November ME102 results for the subset of students with intact scores. The Spargo science test scores and Matric mathematics results were not significant. (For Regression Equations, see Appendix 2: 2.1 and 2.2).

The inclusion of the Matriculation aggregate as a second independent variable does not improve r^2 appreciably. The UCT spatial battery result stands out clearly from the other three independent variables considered as the best single predictor of ME102 engineering drawing examination results in 1983.

(b) Population 2

For full regression equations, see Appendix 2: 2.3 and 2.4). Using the 1984 data for students with intact scores the only independent variable to emerge as a significant predictor of the June and November ME102 engineering drawing results is the Glasgow spatial battery. ($r^2 = 0,66$ in June, $N=232$; $r^2 = 0,60$ in November, $N=216$).

Including the June result in the set of independent variables to predict November results shows the Glasgow spatial battery and the June result as the two significant predictors ($r^2 = 0,79$, $N = 216$).

(c) Population 3

The results are recorded in Table 4.15. Only the Problem-solving/Spatial battery score was found to make a significant prediction (at the 1% level) of June 1985 ME102 results for the subset of students with intact scores ($N=168$). For regression equations, see Appendix 2: 2.5.

At the 5% level, both the Spargo physical science test and the Problem-solving/Spatial battery were significant ($N=177$). However, the inclusion of the Spargo science test as a second independent variable did not improve r^2 appreciably.

The Problem-solving/Spatial battery stands out from the other three independent variables under consideration as the best single predictor of June ME102 examination results in 1985.

The multiple regression results obtained from Populations 1, 2 and 3 and the preceding analyses clearly confirm HYPOTHESES ONE AND TWO, namely that achievement in the June and November ME102

engineering drawing examinations is significantly related to scores obtained in the spatial batteries; and that the spatial batteries are the single best predictors of ME102 engineering drawing results.

4.2 CROSS-CULTURAL STUDY

4.2.1 Comparison of means and T-tests

(a) Population 1

Table 4.16 shows that the ED students as a group scored significantly higher than the DIA group in the UCT spatial battery, Spargo physical science test, June ME102 examination and November ME102 examination.

The ED group scored significantly higher than the DET group in the UCT spatial battery, June ME102 examination and November ME102 examination, but not in the Spargo test.

The DIA group scored significantly higher than the DET group in the November ME102 examination.

Although the numbers of Shell students and non-Shell students are not strictly large enough to test

statistically, it can be seen that the Shell students scored consistently higher marks than their non-Shell peers in the same cultural group.

(b) Population 2

Referring to Table 4.17 it can be seen that the percentage of students lost from the DET and DIA groups (because of absence from examinations, failure to attain DP's, "dropping out" of the course) is much greater than that lost from the ED group. These figures may be overstated since some of the students subsequently may have written supplementary examinations.

Table 4.18 shows that the ED group scored significantly higher than the DIA group in the Glasgow spatial battery (0,01 level), in the Spargo science test (0,1 level) and in the June and November ME102 examinations (0,05 level).

The ED group scored significantly higher than the DET group in the Glasgow spatial battery, Spargo test, and in the June and November ME102 examination (all at 0,01 level).

The DIA group scored significantly higher than the DET group in the Glasgow spatial battery (0,01 level) and the June ME102 examination (0,05 level).

The Shell and non-Shell groups were not tested statistically, but it can be seen clearly that the Shell students scored consistently higher than the non-Shell group.

- (c) Because of the different education systems involved and the different examinations written, it is not feasible to compare matriculation results along cultural lines. However, it is informative to examine the results tabulated in Tables 4.19 and 4.20.

There appear to be no appreciable differences in the achievement of Matriculation mathematics results (presumably as a result of selection procedures used by the university), but there is a marked non-significant drop in average Matriculation aggregates attained across the cultural groups.

No attempt has been made to distinguish between subjects taken on the higher grade or standard grade.

In summary, the first year engineering drawing population can be separated into three statistically significant, distinct groups (ED students, DIA students, DET students) with respect to spatial ability by the spatial batteries.

The same three distinct groups show significantly different June and November ME102 results, thus confirming the predictive validity of the spatial batteries.

The only measure that does not show significantly different achievements across cultural groups is the Spargo physical science test. This finding may be interpreted as evidence that students in the different cultural groups are, overall, equal with respect to both application to academic tasks and general intellectual endowment.

The preceding analysis supports HYPOTHESIS FOUR, namely that there is a significant difference in the performance of students originating in the different education systems provided for each cultural group, with respect to

- (a) Spatial battery results
- (b) June ME102 results
- (c) November ME102 results.

The evidence presented also supports HYPOTHESIS FIVE, i.e. that the Shell Bursary students perform consistently better than their peers of the same cultural group in the spatial batteries and in the engineering drawing course.

4.2.2 Correlation Analysis

(a) Population 1

Correlation matrices were computed for only the 185 students for whom data was available for all 6 measures of

ability (UCT spatial battery, Spargo science test, Matriculation mathematics, Matriculation aggregate, June ME102 and November ME102 results). This sample consisted of:

144 ED students

20 DIA students

18 DET students

Tables 4.21, 4.22 and 4.23 set out the correlation coefficients for each group.

For the DET group, both the UCT spatial battery and the Spargo science test scores correlate significantly with the June ME102 result, but not with the November ME102 result.

For the ED group, several significant correlations are shown between the independent variables and the June and November ME102 results, one of the strongest being that indicated by the UCT spatial battery.

For the DIA group, the only important correlation to emerge was that between the UCT spatial battery score and the November ME102 symbol.

(b) Population 2

Correlation matrices were computed only for those students for whom data was available for the Glasgow spatial battery, Spargo science test, Matriculation mathematics, Matriculation Aggregate, June ME102 and November ME102 results. The sample consisted of:

186 ED students

14 DIA students

10 DET students

Tables 4.24, 4.25 and 4.26 set out the correlation coefficients for each group:

For the DET group, both the Glasgow spatial battery and the Spargo physical science test correlate significantly with the June ME102 result. In November only the Glasgow Spatial battery and June ME102 result shows a significant correlation with the final ME102 result.

For the ED group, both the Spargo physical science test and the Glasgow spatial battery are significantly correlated with June and November ME102 results.

For the DIA group, the Glasgow spatial battery correlates significantly with the June and the November ME102

results. The Spargo physical science test shows a significant correlation with November ME102 results, but not with the June results.

In each case, the highest correlation coefficients calculated are those between the Glasgow spatial battery and the June or November result.

To summarise this section, it can be said that the correlation analysis performed on each cultural group supports HYPOTHESIS THREE, i.e.:

"That the spatial batteries will be the single most powerful predictors of performance in engineering drawing at UCT, irrespective of the cultural group of the sample".

4.2.3 Regression Analysis

Multiple regressions were carried out for each cultural group to find out the best way of predicting June and November ME102 results using the combined independent variables Spatial score, Matriculation mathematics result, Matriculation aggregate, and the Spargo physical science score.

(a) Population 1

DET students (N = 18)

The results for significant predictors are recorded in Table 4.27. Both the UCT spatial score and the Spargo test were found to be significant as predictors of the June ME102 result, but no significant predictors emerged for the November ME102 result.

DIA students (N = 20)

Table 4.28 shows the significant predictors for this population. No significant predictors were found for June ME102; the UCT spatial battery was the only significant predictor for November ME102.

ED students (N = 144)

Significant results of the regression analysis are tabulated in Table 4.29. The UCT spatial battery was shown to be the best predictor for June and November ME102 results.

(b) Population 2

DET and DIA students

The Glasgow spatial score was the only significant predictor to emerge for the June and November ME102 results. For full regression equations, see Appendix 2: 2.6, 2.7, 2.8, 2.9

For ED students, the Glasgow spatial score was the only significant predictor in the June ME102 result, while both the Glasgow spatial score and Matriculation mathematics emerged as significant predictors of the November ME102 results, the latter adding only marginally to the value of r^2 . For full regression equations, see Appendix 2: 2.10, 2.11

Summary

From the preceding multiple regression analyses performed for each cultural group in 1983 and 1984, it is clear that the Spatial battery scores are consistently the best predictors of both June and November ME102 examination results, supporting HYPOTHESES THREE, i.e. that the spatial batteries will be the single most powerful predictors of performance in engineering drawing at UCT, irrespective of the cultural group of the sample.

4.2.4 Comparison of English (first language) group with English (second language) group - 1984

English may be taken as a "First" or "Second" language at matriculation level. English taken as a "Second language" implies that it is not the mother-tongue.

Since language differences and the use or non-use of the mother-tongue play such significant roles in the development of spatial abilities (du Toit, 1966; Deregowski and Munro, 1974; McGurk and Jahoda, 1975; Leach, 1975; Ahmad, 1978) it was decided to compare the performance of those students who passed matriculation English taken as First language (implying English is the mother-tongue) and those who passed English as a Second language (implying English is not the mother-tongue).

Language classifications were obtained for 206 students in 1984:

174 "English first language" - called E1

32 "English second language" - called E2.

From Table 4.30 it can be seen that the matriculation English results (first and second language combined) showed a significant correlation with June 1984 ME102 results but that the English first language only and English second language only groups treated separately, yielded positive but non-significant correlation coefficients.

Means, standard deviations and results of T-tests are shown in Table 4.31. There are significant differences in the results obtained by populations E1 and E2 on the Glasgow Spatial battery, June 1984 ME102 result and November 1984 ME102 result, although, from this information alone, it cannot be concluded that one situation directly causes another.

Forty students either failed or did not write the June ME102 examination. Sixteen (40%) of these belonged to group E2, seventeen belonged to E1 and seven were unclassified. It will be recalled that the University of Cape Town is a fully English-speaking institution, with virtually all lectures being delivered in English.

English as a home language is therefore significantly linked to success in the spatial battery and the engineering drawing course. This result is in accordance with the preceeding cross-cultural results as expected. The majority of the students in group E2 are DET or DIA students. It should be borne in mind that the spatial battery questions were all written in the English language.

HYPOTHESIS SIX "That those students taking English as a first language at matriculation level perform significantly better at engineering drawing examinations (written in English) than those who take English as a second language" is thus supported.

4.3 A COMPARISON OF THE PROBLEM-SOLVING/SPATIAL BATTERY RESULTS OF THE UCT
FIRST YEAR ENGINEERING DEGREE STUDENTS AND CAPE TECHNIKON FIRST YEAR
ENGINEERING DIPLOMA STUDENTS IN 1985

The entrance qualifications required by the Engineering Departments at the Technikon are a D (at least 50%) for Matriculation mathematics and Physical science (Standard grade) or an E (at least 40%) for these two subjects taken on the Higher grade.

At the University of Cape Town, the requirements for 1986 will be a C (at least 60%) for Matriculation mathematics and Physical science taken on the Higher grade.

However, since there were no significant correlations between Matriculation mathematics or the Spargo physical science test (Matriculation level science test) and the spatial battery results in 1983 or 1984, it was not expected that the UCT population would perform better than the Technikon population in the Problem-solving/Spatial test in 1985. In addition, Taylor (1981) found that technical drawing training at school resulted in initial advantages to first year university drawing students. 67% of Technikon students and 47% of UCT students had received some technical drawing at school.

From Table 4.32 it can be seen that although the Technikon students scored lower than the UCT students on both the problem-solving and spatial components of the 1985 battery, the differences are not significant. Thus HYPOTHESIS SEVEN is supported.

TABLE 4.1

POPULATION 1 - JUNE ME102 RESULTS - 1983

SPATIAL SCORES UCT BATTERY		JUNE 1983 EXAMINATION RESULTS IN ENGINEERING DRAWING (ME102)									
	%	N	Ave June %	Drop in average %	NUMBER OF STUDENTS						
					1	2+	2-	3	F	FF	Abs
Excellent	93-100	48	77,1		27	6	12	1	0	0	2
V Good	86-92	46	72,9	4,2	22	12	7	3	2	0	0
Good	80-85	46	68,4	4,5	17	6	14	4	4	1	0
Satisfac- tory	74-79	46	66,2	2,2	13	5	13	11	4	0	0
Borderline	63-73	46	61,5	4,7	12	4	12	8	9	1	0
Fail	0-62	46	41,1	20,4	2	1	6	4	15	16	2
		278	64,6								

Mean spatial battery score = 78,4%

"Pass Mark" for spatial battery = 63%

Abbreviations :

- 1 = 75%
- 2+ = 74% - 70%
- 2- = 69% - 60%
- 3 = 59% - 50%
- F = 49% - 40%
- FF = 39%-
- Abs = Absent
- Ave = Average

TABLE 4.2

POPULATION 1 - NOVEMBER ME102 RESULTS - 1983

SPATIAL SCORES UCT BATTERY			NOVEMBER 1983 EXAMINATION RESULTS IN ENGINEERING DRAWING (ME102)						
	%	N	NUMBER OF STUDENTS						
			1	2+	2-	3	FS	FR	Abs
Excellent	93-100	48	32	9	6	1	0	0	0
V good	86-92	46	22	7	8	6	1	1	1
Good	80-85	46	15	8	13	5	3	1	1
Satis- factory	74-79	46	12	8	12	8	3	1	2
Borderline	63-73	46	10	3	17	9	3	2	2
Fail	0-62	46	2	0	7	14	5	11	7
		278							

Mean spatial battery score = 78,4%

"Pass mark" for spatial battery = 63%

TABLE 4.3

POPULATION 2 - JUNE ME102 RESULTS - 1984

SPATIAL SCORES GLASGOW BATTERY				JUNE 1984 EXAMINATION RESULTS IN ENGINEERING DRAWING (ME102)							
	/66	N	Ave June %	Drop in ave %	Number of students						
					1	2+	2-	3	F	Abs	No DP
Excellent	61-66	56	82		45	1	6	0	0	4	0
Good	56-60	78	78	4	54	7	10	2	3	2	1
Satis- factory	52-55	50	74	4	29	6	7	5	0	3	2
Borderline	47-51	33	64	10	8	4	8	2	6	5	7
Fail	0-46	32	51	13	2	3	5	5	14	3	9
		249	73								

Mean spatial score = $55/66 = 83\%$

"Pass mark" for spatial battery = $47/66 = 71\%$

Abbreviations:

"No DP" means that these students were refused permission to write the November examination in Engineering Drawing due to consistently unsatisfactory performance in weekly practical drawing exercises, and failure in June.

"Ave" = average

TABLE 4.4

POPULATION 2 - NOVEMBER ME102 RESULTS - 1984

SPATIAL SCORES GLASGOW BATTERY				NOVEMBER 1984 EXAMINATION RESULTS IN ENGINEERING DRAWING (ME102)							
	/66	N	Ave Nov %	Drop in ave %	Number of students						
					1	2+	2-	3	F	Abs	No DP
Excellent	61-66	56	74		25	14	12	1	0	4	0
Good	56-60	78	69		24	23	19	8	1	2	1
Satis- factory	52-55	50	67		7	10	24	5	0	2	2
Borderline	47-51	33	62		0	4	14	2	3	3	7
Fail	0-46	32	52		1	1	1	12	7	1	9
		249	67								

Mean spatial score = $55/66 = 83\%$

"Pass mark" for spatial battery = $47/66 = 71\%$

Abbreviations:

"No DP" means that these students were refused permission to write the November examination in Engineering Drawing due to consistently unsatisfactory performance in weekly practical drawing exercises, and failure in June.

TABLE 4.5

A COMPARISON OF THE JUNE AND NOVEMBER ME102 EXAMINATION RESULTS

OF THOSE STUDENTS CLASSIFIED "BORDERLINE" OR "FAIL"

IN THE GLASGOW SPATIAL BATTERY

GIVEN IN FEBRUARY

ME102 Examination Results	No. of Students June	No. of Students November
Fail (< 50%)	20	10
Third Class (50 - 59%)	7	14
Lower Second (60 - 69%)	13	15
Upper Second (70 - 74%)	7	5
First Class (75 - 100%)	10	1

TABLE 4.6

POPULATION 5 - COMPARISON OF SCORES
OF FIRST AND SECOND ATTEMPT AT GLASGOW SPATIAL BATTERY
AND JUNE AND NOVEMBER ME102 RESULTS

Student	Spatial battery Attempt No. 1		Spatial battery Attempt No. 2		June ME102	Nov ME102
	Score /66	category	Score /66	category		
A	49	Borderline	61	Excellent	73%	65%
B	46	Fail	55	Satisfactory	98%	75%
C	49	Borderline	53	Satisfactory	84%	60%
D	47	Borderline	54	Satisfactory	75%	69%
E	45	Fail	51	Borderline	74%	50%
F	43	Fail	40	Fail	74%	56%
G	40	Fail	44	Fail	78%	58%

TABLE 4.7

POPULATION 3 - JUNE ME102 RESULTS - 1985

SPATIAL SCORES ONLY OF PROBLEM-SOLVING/SPATIAL BATTERY					JUNE 1985 EXAMINATION RESULTS IN ENGINEERING DRAWING (ME102)					
					NUMBER OF STUDENTS					
	/90	N	Ave June %	Drop in ave %	1	2+	2-	3	Fail	Abs
Excellent	66-90	20	78,3		14	2	3	0	1	0
Good	56-65	50	78,9	-	28	9	9	0	0	4
Satis- factory	46-55	56	74,0	4,9	29	3	10	4	4	6
Borderline	36-45	46	71,3	2,7	20	5	7	5	5	4
Fail	0-35	33	61,5	9,8	5	4	8	5	4	7
		205	72,6							

Mean spatial score = $49/90 = 54,1\%$

"Pass mark" for Spatial section only of

Problem-solving/Spatial battery = $35/90 = 39\%$

TABLE 4.8

POPULATIONS 1, 2 AND 3 - COMPARISON OF ME102 EXAMINATION RESULTS
OF THOSE STUDENTS WHO FAILED THE SPATIAL BATTERIES
WITH THOSE WHO PASSED THE SPATIAL BATTERIES.

	SPATIAL FAIL			SPATIAL PASS			T-VALUE	SIGNIFICANCE LEVEL
	\bar{x}	SD	N	\bar{x}	SD	N		
1983 June ME102	45,7%	18,9%	34	69,9%	13,5%	212	7,2	0,01
1983 Nov ME102	52,1%	12,9%	34	69,2%	11,6%	212	7,9	0,01
1984 June ME102	50,7%	19,8%	29	77%	13%	203	7,0	0,01
1984 Nov ME102	52,4%	9,0%	22	69,3%	8,9%	194	8,4	0,01
1985 June ME102	61,2%	16,3%	30	75,5%	13,6%	155	5,1	0,01

TABLE 4.9

POPULATIONS 1, 2 AND 3 - COMPARISON OF SPATIAL SCORES
OF THOSE STUDENTS WHO FAILED THE JUNE ME102 EXAMINATION
WITH THOSE WHO PASSED ME102

	JUNE FAIL			JUNE PASS			T-VALUE	SIGNIFICANCE LEVEL
	\bar{x}	SD	N	\bar{x}	SD	N		
1983 UCT Battery	59%	18,5%	37	81,9%	12,4%	209	7,2	0,01
1984 Glasgow Battery	36,2%	9,9%	23	77,8%	11,0%	209	17,3	0,01
1985 Problem- solving/Spatial Battery	42%	10,9%	15	54%	13,1%	170	3,3	0,05

TABLE 4.10

POPULATIONS 1 AND 2 - COMPARISON OF SPATIAL SCORES
OF THOSE STUDENTS WHO FAILED THE NOVEMBER ME102 EXAMINATION
WITH THOSE WHO PASSED ME102

	NOV FAIL			NOV PASS			T-VALUE	SIGNIFICANCE LEVEL
	\bar{x}	SD	N	\bar{x}	SD	N		
1983 UCT Battery	63,4%	18,9%	27	80,3%	14,3%	219	4,5	0,01
1984 Glasgow Battery	68,6%	13,6%	12	84,7%	9,1%	204	5,8	0,01

TABLE 4.11

POPULATION 1 - CORRELATION MATRIX FOR 185 ENGINEERING DRAWING STUDENTS
WITH COMPLETE DATA FOR 1983

	UCT Spatial Battery	Spargo Physical Science	Matric Maths Symbol	Matric Aggregate Symbol	June ME 102 Test	November ME 102 exam Symbol
UCT Spatial Battery	1,00	0,30*	-0,02	0,19*	0,65* (N=273)	0,52*
Spargo Physical Science Test		1,00	0,10	0,46*	0,20*	0,26*
Matric Maths Symbol			1,00	0,12	-0,01	0,00
Matric Aggre- gate Symbol				1,00	0,27*	0,36*
June ME 102 Test					1,00	0,77*
November ME 102 Exam Symbol						1,00

* Significant Correlations: $r > 0,14$ $p < 0,05$

TABLE 4.12

POPULATION 2 - CORRELATION MATRIX FOR 232 ENGINEERING DRAWING STUDENTS
WITH COMPLETE DATA FOR 1984

	Glasgow Spatial Battery	Spargo Physical Science	Matric Maths Symbol	Matric Aggregate Symbol	June ME102 Test	November ME102 Exam Symbol
Glasgow Spatial Battery	1	0,32*	0,12	0,17*	0,66*	0,60* (N=216)
Spargo Physical Science		1	0,40*	0,46*	0,29*	0,3*
Matric Maths Symbol			1	0,54*	0,10	0,22*
Matric Aggregate Symbol				1	0,12	0,17*
June ME102 Test					1	0,76
November ME102 Exam Symbol						1

* Significant correlations $r > 0,14$ $p < 0,05$

TABLE 4.13

POPULATION 3 - CORRELATION COEFFICIENTS FOR JUNE 1985 ME102 RESULTS
WITH PROBLEM-SOLVING/SPATIAL BATTERY (PER SECTION) AND
MATRICULATION SYMBOLS

June ME102 1985

Problems (Part 1)	0,35*
Problems (Part 2)	0,22*
Problems (Total)	0,36*
Spatial section only	0,38*
Problems (Part 1) & Spatial section	0,40*
Total test	0,41*
Matric maths	0,18*
Matric aggregate	0,17*
Matric English	0,18*
Matric Science	0,20*
Spargo Science	0,28*

* Significant correlations $r > 0,14$ $p < 0,05$

TABLE 4.14

POPULATION 1 - REGRESSION ANALYSIS - 1983

(N = 185)

SIGNIFICANT PREDICTORS	June 1983	SIGNIFICANT PREDICTORS	Nov 1983
1. UCT spatial battery	$r^2 = 0,54$	1. UCT spatial battery	$r^2 = 0,52$
2. UCT spatial battery + Matriculation aggregate	$r^2 = 0,57$	2. UCT spatial battery + Matriculation aggregate	$r^2 = 0,58$

TABLE 4.15

POPULATION 3 - REGRESSION ANALYSIS - 1985

(N = 185)

Significant predictors	June 1985
1. Problem-solving/Spatial battery	$r^2 = 0,41$
2. Problem-solving/Spatial battery + Spargo physical science test	$r^2 = 0,45$

TABLE 4.16

COMPARISON OF THE AVERAGE PERFORMANCE OF DIFFERENT CULTURAL GROUPS

IN THE UCT SPATIAL BATTERY, SPARGO PHYSICAL SCIENCE TEST,

JUNE AND NOVEMBER ME102 EXAMINATION 1983

Cultural Groups	N	Spatial Score %	% Difference	Spargo Science Score %	% Difference	ME102 June %	% Difference	ME102 Nov %	% Difference
ED Students	206	80,7		64		68,9		69,2	
DIA Students	26	68,6	-12,1*	56,7	-7,3*	53,2	-15,7*	61,5	-7,7*
DET Students	23	62,9	-17,80*	62,1	-1,9	46	-22,90*	51	-18,20*
Shell Students	14	69,9		73		55,2		58,4	
Non-Shell Students	12	56	-13,9	50,1	-22,9	39,3	-15,9	46,7	-11,7

* Difference significant at 0.01 level

TABLE 4.17

REDUCTION IN STUDENT NUMBERS DURING THE YEAR 1984
DUE TO ABSENTEES, DROPOUTS AND THOSE REFUSED DP'S

	No. tested in Feb.	No. writing June ME102	No. writing Nov ME102	% lost by Nov
ED Students	202	191	186	7,9
DIA Students	23	19	15	34,8
DET Students	22	20	13	40,9
Shell students	14	14	12	14,3
Non-Shell students	31	25	16	48,4

TABLE 4.18

COMPARISON OF THE AVERAGE PERFORMANCE

OF DIFFERENCE CULTURAL GROUPS

IN THE GLASGOW SPATIAL BATTERY, SPARGO PHYSICAL SCIENCE TEST

JUNE AND NOVEMBER ME102 EXAMINATION 1984

Cultural Groups	N	Spatial Score %	% Difference	Spargo Science Score %	% Difference	ME102 June %	% Difference	ME102 Nov %	% Difference
ED Students	202	85,1		61,8		76,7		78,8	
DIA Students	23	77,2	- 7,9	55,3	-6,5	66,5	-10,2	60,2	-18,6
DET Students	22	64,9	-20,2	52,2	-9,6	52	-24,7	57,1	-21,7
Shell students	14	77,2		65,1		70,5		62,0	
Non-Shell Students	31	68,5	- 8,7	47,9	-17,2	52,6	-17,9	56,3	- 5,7

TABLE 4.19
COMPARISON OF THE AVERAGE PERFORMANCE
OF DIFFERENCE CULTURAL GROUPS
IN MATRIC MATHEMATICS AND MATRIC AGGREGATE (1983)

Cultural Groups	N	Maths %	Aggregate %
ED Students	206	64,8	67,3
DIA Students	26	66,9	61,9
DET Students	23	65,7	59,0
Shell students	14	68,5	65,4
Non-shell students	12	64,6	54,4

TABLE 4.20

COMPARISON OF THE AVERAGE PERFORMANCE

OF DIFFERENT CULTURAL GROUPS

IN MATRIC MATHEMATICS AND MATRIC AGGREGATE (1984)

Cultural groups	N	Maths %	Aggregate %
ED Students	202	67,1	66,3
DIA Students	23	64,8	63,5
DET Students	22	63,6	59,1
Shell students	14	70,0	67,9
Non-Shell students	31	61,6	58,4

TABLE 4.21

POPULATION 1 - CORRELATION MATRIX FOR
18 DET ENGINEERING DRAWING STUDENTS 1983

	UCT Spatial Battery	Spargo Physical Science	Matric Maths Symbol	Matric Aggregate Symbol	June ME102 Result	November ME102 Symbol
UCT Spatial Battery	1	0,48*	0,22	0,52*	0,48*	0,28
Spargo Physical Science test		1	0	0,62*	0,49*	0,42
Matric Maths Symbol			1	0,29	0,19	0,19
Matric Aggregate Symbol				1	0,40	0,13
June ME 102 Result					1	0,69*
November ME 102 Symbol						1

* Significant correlations:

$r > 0,44$ $p < 0,05$

TABLE 4.22

POPULATION 1 - CORRELATION MATRIX FOR
144 ED ENGINEERING DRAWING STUDENTS 1983

	UCT Spatial Battery	Spargo Physical Science	Matric Maths Symbol	Matric Aggregate Symbol	June ME102 Result	November ME102 Symbol
UCT Spatial Battery	1	0,30*	0,12	0,07	0,49*	0,47*
Spargo Physical Science test		1	0,48*	0,47*	0,17	0,25*
Matric Maths Symbol			1	0,68*	0,19*	0,28*
Matric Aggregate Symbol				1	0,17	0,33*
June ME 102 Result					1	0,73*
November ME 102 Symbol						1

* Significant correlations:

$r > 0,17$ $p < 0,05$

TABLE 4.23

POPULATION 1 - CORRELATION MATRIX FOR
20 DIA ENGINEERING DRAWING STUDENTS 1983

	UCT Spatial Battery	Spargo Physical Science	Matric Maths Symbol	Matric Aggregate Symbol	June ME102 Result	November ME102 Symbol
UCT Spatial Battery	1	-0,01	-0,04	-0,04	0,38	0,49*
Spargo Physical Science Test		1	0,05	0,33	-0,16	0,12
Matric Maths Symbol			1	0,62*	0,08	-0,04
Matric Aggregate Symbol				1	-0,01	0,02
June ME102 Result					1	0,74*
November ME102 Symbol						1

* Significant correlations:

$r > 0,42$ $p < 0,05$

TABLE 4.24

POPULATION 2 - CORRELATION MATRIX FOR
10 DET ENGINEERING DRAWING STUDENTS 1984

	Glasgow Spatial Battery	Spargo Physical Science	Matric Maths Symbol	Matric Aggregate Symbol	June ME102 Result	November MR102 Symbol
Glasgow Spatial Battery	1	0,68*	0,23	-0,09	0,87*	0,67*
Spargo Physical Science Test		1	0,23	0,28	0,72*	0,46
Matric Maths Symbol			1	0,73*	0,13	0,56
Matric Aggregate Symbol				1	0,14	0,37
June ME102 Result					1	0,74*
November ME102 Symbol						1

Significant correlations:

$r > 0,58$ $p < 0,05$

TABLE 4.25

POPULATION 2 - CORRELATION MATRIX

FOR 186 ED ENGINEERING DRAWING STUDENTS 1984

	Glasgow Spatial Battery	Spargo Physical Science	Matric Maths Symbol	Matric Aggregate Symbol	June ME102 Result	November ME102 Symbol
Glasgow Spatial Battery	1	0,26*	0,16*	0,12	0,49*	0,52*
Spargo Physical Science Test		1	0,42*	0,45*	0,21*	0,21*
Matric Maths Symbol			1	0,54*	0,13	0,09
Matric Aggregate Symbol				1	0,07	0,73*
June ME102 Result					1	
November ME102 Symbol						1

Significant correlations:

$r > 0,14$ $p < 0,05$

TABLE 4.26

POPULATION 2 - CORRELATION MATRIX
FOR 14 DIA ENGINEERING DRAWING STUDENTS 1984

	Glasgow Spatial Battery	Spargo Physical Science	Matric Maths Symbol	Matric Aggregate Symbol	June ME102 Result	November ME102 Symbol
Glasgow Spatial Battery	1	0,54*	-0,12	0,21	0,72*	0,78*
Spargo Physical Science Test		1	0,26	0,63*	0,45	0,51*
Matric Maths Symbol			1	0,52*	-0,10	-0,05
Matric Aggregate Symbol				1	0,24	0,45
June ME102 Result					1	0,93*
November ME102 Symbol						1

Significant correlations:

$r > 0,50$ $p < 0,05$

TABLE 4.27

POPULATION 1 - DET STUDENTS - REGRESSION ANALYSIS

(N = 18)

Significant Predictors	ME102 June 1983
1. Spatial Battery	$r^2 = 0,48$
2. Spargo Science test	$r^2 = 0,49$

TABLE 4.28

POPULATION 1 - DIA STUDENTS - REGRESSION ANALYSIS

(N = 20)

Significant Predictors	ME102 Nov. 1983
1. Spatial battery	$r^2 = 0,49$
2. Spatial score* + Science test + Matric maths + Matric aggregate	$r^2 = 0,51$

* Only spatial score is significant in regression equation

TABLE 4.29

POPULATION 1 - ED STUDENTS - REGRESSION ANALYSIS

(N = 144)

Significant Predictors	ME102 June 1983	Significant Predictors	ME102 Nov 1983
1. Spatial battery	$r^2 = 0,49$	1. Spatial battery	$r^2 = 0,47$
		2. Spatial battery + Matric aggregate	$r^2 = 0,56$

TABLE 4.30

A COMPARISON OF SIGNIFICANT CORRELATIONS
CALCULATED BETWEEN SELECTED INDEPENDENT VARIABLES
AND THE CRITERION SCORE JUNE 1984 ME102

Glasgow Spatial Battery		Spargo Physical Science	Matric English Results '83 (All)	Matric English Results 1st Lang.	Matric English Results 2nd Lang.
1984	N = 214	N = 214	N = 206	N = 174	N = 32
June	r = 0,66*	r = 0,22*	r = 0,15*	r = 0,09	r = 0,15
ME102				Not	Not
Result				Significant	Significant

* Significant, $p < 0,05$

$r > 0,14$

TABLE 4.31

A COMPARISON OF THE PERFORMANCE OF
ENGLISH FIRST LANGUAGE STUDENTS WITH
ENGLISH SECOND LANGUAGE STUDENTS

	English First Language (Population E1)			English Second Language (Population E2)				
1984	N	Mean %	SD %	N	Mean %	SD %	T	p
Glasgow Spatial Battery	169	85,2	8,9	22	73,9	13,2	3,9	0,01
June ME102 Result	174	77,07	13,3	32	56,09	22,6	5,1	0,01
November ME102 Result	169	68,3	9,9	22	60,4	11,5	3,5	0,01

TABLE 4.32

A COMPARISON OF UCT AND TECHNIKON STUDENTS' RESULTS
IN THE 1985 PROBLEM-SOLVING/SPATIAL BATTERY

	Problem solving component			Spatial component	
	N	Mean %	SD %	Mean %	SD %
UCT Students	214	41,7	12,8	54,1	15,6
Technikon Students	178	38,2	11,1	49,4	14,8

CHAPTER FIVE

DISCUSSION, CONCLUSIONS AND RECOMMENDATIONS

In this final chapter a brief summary of the present investigation is presented with reference to the major findings, and recommendations are made for future research.

5.1 PREDICTION OF ME102 RESULTS

The three different spatial batteries used during 1983, 1984 and 1985 were all shown to be the most important predictors of the ME102 results in June and in November, and in many instances were found to be even better predictors than those utilised at the University of the Witwatersrand.

It is clear that the predictive validity of these pencil-and-paper tests of spatial ability decreases with increasing time (from June to November) probably due to the spatial learning that occurs by students during the academic year. It should also be noted that the November ME102 results are modified by the examiner while the results of the June test are left unmodified, which may account for the better prediction of the mid-year scores.

Rochford (1984) observed the same phenomenon and attributed the decline in predictive validity to the hypothesis that spatial learning occurs during the academic year.

The implication of this finding is that university lecturers are strongly advised not to use spatial tests as a tool to exclude prospective students from a course of study in engineering drawing.

The major advantage of using a spatial test on a group of first year students is that the scores give an indication of those students likely to need special academic support in this area - either in the form of special remedial drawing classes, or possibly being advised to take the five-year degree course instead of the four-year option at the University of Cape Town.

Other measures of the students' ability which are available (e.g. Matriculation symbols) do not give any significant insights into potential problems in the area of engineering drawing.

The successful selection of students for special academic support in engineering drawing using the results of pencil-and-paper tests of spatial ability has also occurred at the University of the Witwatersrand. The resulting improvement of the pass rate in the EAD course bears out the success of the project as a whole.

In 1985 at UCT, the first small group of engineering students has been selected for an academic support course in engineering drawing, using (among other indicators of performance) their spatial scores on the Problem-solving/Spatial battery. However there is still scope for a great deal of research in refining the spatial batteries to improve predictive validities, and for following through the progress of those students receiving academic support in order to assess the effectiveness of the courses.

5.2 DESIGN OF A DIAGNOSTIC/PREDICTIVE BATTERY

In an attempt to optimise the design of a diagnostic/predictive battery, three different batteries were used during 1983, 1984 and 1985.

The UCT spatial battery (1983) and the Glasgow spatial battery (1984) were fairly similar in format. The time limits set allowed most students to complete all the questions. The resulting correlation coefficients calculated with June and November ME102 results were similar.

The Problem-solving/Spatial battery (1985) was a combination of the sort of spatial questions set in previous years (Sections three and four) and two new sections covering problem-solving (Sections one and two). The time limits set allowed very few, if any, candidates to complete each section.

It was surprising to note that both the UCT and the Technikon students fared so poorly in Section two (consisting of thirteen problems) compared to Section one (consisting of twelve problems) (see Table 3.3). The problems in each section were selected randomly from a group of twenty-five problems, the only consideration being that of keeping the spread across the different varieties of problem uniform in both sections. The same time period was allowed in each case. Section two was therefore not intended to be more difficult than Section one.

The explanation suggested by the drawing lecturer was that the students found the overall test too long and rather difficult, so became tired and disheartened. Section two was poorly answered and the drop in correlation coefficients with June ME102 from 0,35 (for Section one) to 0,22 (for Section two) reflects this.

A feeling of discouragement about the length and difficulty of the test may also account for the low averages achieved in the Spatial area (Sections three and four) in 1985 compared to the results of previous years. Sections three and four were fairly similar to the Glasgow and UCT Spatial batteries where engineering first year students scored ^{means of} 82,9% and 74,4% respectively (see Tables 3.1, 3.2 and 3.3). Correlations between the spatial portion (Sections three and four) and June ME102 were very much lower than those calculated in previous years. It is intended to reverse the order of the test in the future, placing the spatial section first, with Problems: Section one second and omitting Problems: Section two altogether.

The Problem-solving scores may be used for the long-term prediction of success in engineering studies in later years of the B.Sc. (Eng) degree, but this awaits further investigation.

It has been established that remedial work with students having good spatial ability, but poor problem-solving ability (as indicated by the tests) is not as effective as remedial work with students having poor spatial ability but good problem-solving ability at the University of the Witwatersrand. (Van der Merwe, 1984: Private communication).

Further research into the spatial abilities and academic support needs of engineering students should investigate the problem-solving aspect in greater detail. This links up with the work done by Potter and van der Merwe (1983; 1984) at the University of the Witwatersrand, and the opinions expressed by Kemp (1983) on the importance of problem-solving in successful engineers.

5.3 CROSS-CULTURAL STUDY

The mean spatial battery scores of the students from the three distinct "cultural" groups are clearly different. The same three groups also show significantly different June and November ME102 results. However, there are no significant differences between the Matriculation mathematics mark achieved within each separate education system provided for each group (Department of Education and Training for Blacks, Department of Internal Affairs for Coloureds, and Department of Education for Whites).

The implication of this finding underlines the huge disparities in the home background and/or quality of education offered by the different systems and the problems faced by those students who are products of an inferior and inadequate social system. An urgent need for reform in the official education system in South Africa is emphasised. All efforts must be made to provide education of equal quality with respect to standard of teaching, curricula and educational facilities, irrespective of race group.

This is further suggested by the fact that the Shell scholars, who are exposed to the "White" education system for a post-matric year at a private school, performed significantly better than their Non-Shell peers of the same cultural groups who emerge from the same educational systems (although the former were selected on merit and potential).

The incorporation of technical drawing into the curriculum at high school level for those students wishing to pursue a scientific career may be a good idea. Rochford (1984) points out in his work with anatomy and astronomy students that poor spatial ability is associated with problems in the pursuit of many scientific subjects.

The findings on the effectiveness of any special academic support methods developed will be of great use for improving education methods in all schools, but will be of particular interest in the Black and Coloured communities where the educational needs of the school-going population as well as the adult population are the greatest.

5.4 CONCLUSIONS

The main conclusions from this three-year investigation may be summarized as follows:

1. Achievement in the mid-year (June) and final (November) engineering drawing examinations (ME102) has been shown to be significantly related to scores obtained in pencil and paper tests of spatial ability given on or before commencement of lectures.

2. It has been shown that the different spatial batteries used in each successive year are the single most powerful predictors of performance in engineering drawing. This result holds true irrespective of the cultural group of the sample.
3. There is a significant difference in the performance of students originating in the different education systems provided for each cultural group, with respect to spatial battery results and mid-year and year-end engineering drawing results.
4. The Shell bursary students perform significantly better than their peers of the same cultural group and who originated from the same education system, at both the spatial battery and the engineering drawing course.
5. Students taking English as a first language at matriculation level (implying English is the mother-tongue) perform significantly better at engineering drawing at UCT than those taking English as a second language (implying English is not the mother-tongue).
6. The performance of UCT first year engineering degree students in the Problem-solving/Spatial battery is not significantly different from that of Technikon first year engineering diploma students in the same geographical region of the Cape Peninsula of South Africa.

LIST OF REFERENCES

- Ahmad, M.M.R. (1978)
The Effect of Language on the Identification of Pictorial Stimuli.
Programmed Learning and Educational Technology 15 (1) pgs 35-41,
February.
- Alonge, E.I. (1977)
An Investigation of the Effects of Language on the Understanding of
Spatial Relationships by Nigerian Secondary School Children.
Unpublished M.Sc Dissertation, University of East Anglia.
- Behr, D. (1982)
The Prediction of Academic Performance of First Year Engineering
Students.
South African Journal of Education 2(3), pgs 89-95.
- Bermingham, P.J. (1976)
Are Ideas in Three Dimensions Beyond You?
Times Higher Education Supplement 5 November : 11.
- Berry, J.W. (1966)
Temne and Eskimo Perceptual Skills.
International Journal of Psychology 1, pgs 207-229.
- Bishop, A.J. (1979)
Developing Spatial Abilities.
Mathematics Education Centre, Report No. 4, Papua New Guinea
University of Technology, Lae.
- Blade, M.F. & Watson, W.S. (1955)
Increases in Spatial Visualization Test Scores During Engineering
Study. Psychology Monographs, vol. 69, No. 12 pgs 1-13.
- Bridgeman, P.W. (1958)
Quo Vadis?
Daedalus 87 pgs 85-93
- Bruner, J.S. (1973)
Beyond the Information Given
New York, Norton.
- Burt, C (1940)
The Factors of the Mind
University of London Press.
- V.Cattell, R.B. (1943)
The Measurement of Adult Intelligence
Psychological Bulletin Vol. 40, No. 3, March 1943.

Coppen, H. (1970)

Visual Perception: A Review of the Literature Relating to Studies Relevant to the Development of Teaching Materials in the Commonwealth.

London: Commonwealth Secretariat

Corporate Responsibility: Sullivan Code Signatories aid Regeneration of Black Education.

Management, April 1985, pgs 36-38.

Davies, R.C. (1984)

Some Considerations in the Development of a Multicultural Curriculum for Namibia.

Education Journal pgs 29-36.

Davies, T.N. (1976)

The Span of Visual Perception in Engineering Drawing.

The Communicator of Scientific and Technical Information, England, April, pgs 2-11.

Cited in Kemp (1983), p 258.

Davies, T.N. (1982)

Visual Perception Associated with the Graphic Communication of Information.

Research Scheme R3128, Ministry of Overseas Development, Chester, England, January.

Cited in Kemp (1983), p 258.

Dawson, J.L.M. (1967)

Cultural and Physiological Influences upon Spatial-perception Processes in West Africa: Part 1.

International Journal of Psychology, Vol 2, pgs 115-128.

Dawson, J.L.M. & Young, B.M. (1974)

Developmental Influences in Pictorial Depth Perception among Hong Kong Chinese Children.

Journal of Cross-cultural Psychology, Vol. 5, No. 1, March pgs 3-20.

Deregowski, J. B. & Blyth, W. (1970)

Hudson's Pictures in Pandora's Box.

Journal of Cross-cultural Psychology Vol 1, No. 4 December pgs 315-323.

Deregowski, J.B. (1972)

Pictorial Recognition in a Remote Ethiopian Population.

Perception. Vol 1, pgs 417-425

Deregowski, J.B. (1974)

Teaching African Children Pictorial Depth Perception: In Search of a Method.

Perception, Vol 3, pgs 309-312

- Deregowski, J.B. & Munro, D. (1974)
An Analysis of "Polyphasic pictorial Perception".
Journal of Cross-cultural Psychology, Vol 5, No. 3, September pgs 329-343
- Deregowski, J.B. (1976)
Coding and drawing of simple geometric stimuli by Bukusu school children in Kenya.
Journal of Cross-cultural Psychology Vol 7, No. 2, June pgs 195-208.
- Dos Santos Veiga, J. & Seddon, G.M. & Jusoh, I. (1981)
Testing the understanding of pictorial spatial relationships using the Portuguese and Malay languages.
Educational Psychology Vol 1, No. 4, pgs 305-317.
- Dostal, E & Vergnani, T. (1984)
Future perspectives on South African education.
Occasional Paper No. 4, Business series, Social Environment, Institute for Futures Research, University of Stellenbosch.
- Du Toit, B.M. (1966)
Pictorial Depth Perception and Linguistic Relativity.
Psychologia Africana 11: pgs 51-63.
- Edmunds, J. (1974)
A - E Firm Bridges Color Barrier
Consulting Engineer, 42, 6, 112, 114, June.
- E1 Koussy, A.A.H. (1935)
The Visual Perception of Space.
Ph.D. Thesis in British Journal of Psychology, Monograph Supplement, Cambridge University Press.
- E1 Koussy, A.A.H. (1955)
The Directions of Research in the Domain of Spatial Aptitudes.
Edition of the Centre National de la Recherche Scientifique, Paris.
- Franklin, M.B. (1969)
A Study of Non-verbal Representation in Young Children.
Paper Presented at the Meeting of the National Association for the Education of Young Children, Salt Lake City, Utah, November 14.
- Gagne, R.M. (1963)
The Conditions of Learning.
Holt, Rinehart and Winston.
- Garay, M.S. (1983)
Adapting Tagmemic Theory for Early Entry Black Engineering Students at a Southern University.
Paper presented at the Annual Meeting of the Conference on College Composition and Communication (34th, Detroit, MI, March 17 - 19, 1983).

- Greene, A. (1979).
Tomorrow's Technical Talent.
Changes, V11 N7 pgs 16 - 18, October.
- Guilford, J.P. (1956)
The Structure of Intellect.
Psychological Bulletin, Vol 53, pgs 267-293.
- Hewson, M.G.A. (1982)
Students' Existing Knowledge as a Factor Influencing the Acquisition of Scientific Knowledge. Unpublished Ph.D. Thesis, University of the Witwatersrand, South Africa.
- Ho, K. (1974)
Exploratory Study of Spatial Dimensionality Across two Ethnic Groups.
Unpublished Ph.D. Dissertation, University of Maryland.
- Holloway, G.E.T. (1967)
An Introduction to the Child's Conception of Geometry.
Routledge and Kegan Paul Ltd.
- Hudson, W. (1960)
Pictorial Depth Perception in Sub-Cultural Groups in Africa.
Journal of Social Psychology 52, pgs 183-208 reprinted in
Cross-Cultural Studies in Behaviour (1970).
- Hudson, W. (1962)
Cultural Problems in Pictorial Perception.
South African Journal of Science, Vol 58, pgs 189-196.
- Hudson, W. (1967)
The study of the problem of pictorial perception among unacculturated groups.
International Journal of Psychology 2: pgs 89 - 107 reprinted in
Cross-cultural Studies, 1969.
- Hyman, B.S. (1982)
The Role of Student Manipulation of Molecular Models and Spatial Visualisation Ability on Achievement in College Level Organic Chemistry.
Unpublished Ph.D., Columbia University Teachers College.
- Kemp, A. (1983)
Graphicacy and Literacy in Engineering Education.
The South African Mechanical Engineer, Vol. 33, September,
pgs 256-260
- Kiehl, R. (1971)
Opportunities for Blacks in Engineering - A Third Report.
Personnel and Guidance Journal, 50, 3, pgs 204 - 208, November.

Leach, M.L. (1975)

The Effect of Training on the Pictorial Depth Perception of Shona children.

Journal of Cross-cultural Psychology Vol. 6, No. 4, December pgs 457-470.

Lean, G.A. (1980)

An Investigation of Spatial Ability among Papua New Guinea Students.
Mathematics Education Centre, Papua New Guinea University of Technology, Report No. 4.

Lloyd, P.J.D. & Plewman, R.P. (1984)

The Supply and Demand for Engineers.

Report by the Federation of Societies of Professional Engineers.

Macrae, M. (1974).

Connexions between local cultures and mathematical education.
Educational Development International 2 (2) pgs 85 - 89.

Marsicano, A.J. (1975)

The Prediction of Academic Success in Engineering Technology.
Engineering Education, Vol 66, pgs 268-271.

McGurk, H. & Jahoda, G. (1975).

Pictorial Depth Perception by Children in Scotland and Ghana.

Journal of Cross-cultural Psychology, Vol 6, No. 3, September pgs 279-296.

Michael, W.B., Guilford, J.P., Fruchter, B. & Zimmerman, W.S. (1957).

The Description of Spatial-visualization Abilities.

Educational and Psychological Measurement, Vol. 17, pgs 185-199.

Mitchelmore, M.L. (1980)

Three Dimensional Geometrical Drawing in Three Cultures.
Educational Studies in Mathematics II (2), pgs 205-216.

Nicholson, J.R. (1974)

An Exploratory Study into the Perception of Spatial Relationships in Diagrams of Framework Structures by Nigerian University Science Students and Secondary School Pupils.

Unpublished M.Sc. Dissertation, University of East Anglia.

Nicholson, J.R. & Seddon, G.M. & Worsnop, J. (1977)

Teaching the Understanding of Pictorial Spatial Relationships to Nigerian Secondary School Students.

Journal of Cross-cultural Psychology 8 (4) pgs 401-414.

Omari, I.M. and Cook, H. (1972)

Differential Cognitive cues in Pictorial Depth Perception.

Journal of Cross-cultural Psychology Vol. 3, No. 3, September pgs 321-325.

Pettersson, R. (1982)

International Review: Cultural Differences in the Perception of Image and Color in Pictures.

ECTJ, Vol 30, No. 1, pgs 43-53.

Piaget and Inhelder (1956).

The Child's Conception of Space.

Routledge and Kegan Paul Ltd.

Poole, H. (1969).

Restructuring the perceptual world of African children.

Teacher Education in New Countries 10 : pgs 165 - 175.

Porter, C.F. (1982).

The Effects of Two-dimensional, Three-dimensional, and a Combination of Two- and Three-dimensional Instructional Strategies on the Achievement of High School Biology Students with varying levels of Spatial Visualization Ability, Cognitive Development and Gender.

Unpublished Ed. D., University of Georgia.

Potter, C.S. & van der Merwe, E. (1982).

Draft Report on the Special EAD Course Undertaken by the Engineering Faculty at the university of the Witwatersrand during 1981.

Internal Report, University of the Witwatersrand, Johannesburg.

Potter, C.S. & van der Merwe, E. (1983).

Report on Study Visit to Engineering Programmes in USA, Canada, Britain and Israel.

Internal Report, University of the Witwatersrand, Johannesburg.

Potter, C.S. & van der Merwe, E. (1984).

The Identification and Support of Students with Weaknesses in Engineering Drawing at University Level.

Discussion Paper No. 4, Occasional Paper Series in Adult and Continuing Education, University of the Witwatersrand, Johannesburg.

Potter, C.S., van der Merwe, E. & Kemp, A. (1984).

The Development of an Approach to Identifying and Remediating Weaknesses in Engineering Analysis and Design at First Year University Level.

Unpublished paper presented at the Committee of University Principals' Conference on Teaching and Learning at Universities in South Africa. Bloemfontein, 3-5 September.

Potter, C. & Meyer, M.I. & Scott, A.S. & da Silva, M. (1984).

Study Habits and Attitudes of Students in five Engineering Disciplines.

Undergraduate Cadet Scheme, University of the Witwatersrand. Working Paper 18.33.

Project P.A.C.E. Final Report 1983 - 1984.

Brookdale Community Centre, Lincroft, N.J., July.

Sponsoring Agency: New Jersey State Department of Education, Trenton Division of Vocational Education and Career Preparation.

- Rochford, K. (1985).
Spatial Learning Disabilities and Underachievement among University Anatomy Students.
Medical Education, 19, 13-26.
- Rolfe, J.M. (1980).
Correlation Between Spatial Perception Aptitude Tests and the Brohn-Cowan Tests of Understanding of Structural Behaviour.
Presented at the Workshop of Spatial Perception University of the Witwatersrand, April 1980.
- Ross, A.R. (1977)
The Remedial Treatment of Problems of Depth Perception in Diagrams: A Nigerian Study.
Unpublished M.Sc. dissertation University of East Anglia.
- Sinha, D. & Shukla, P. (1974).
Deprivation and Development of Skill for Pictorial Depth Perception.
Journal of Cross-cultural Psychology Vol 5, No. 4, December pgs 434-450.
- Smith, I.M. (1960).
The Validity of Tests of Spatial Ability as Predictors of Success on Technical Courses.
British Journal of Education Vol 30 Part 2.
- Smith, I.M. (1964).
Spatial Ability: Its Educational and Social Significance.
University of London Press.
- A Study of Visual Perception in Early Childhood. (1967)
Western New Mexico University, Silver City, Report No. OEO-2400
Sponsoring Agency: Office of Education (DHEW), Washington, D.C.
- Tassell, A. (1985).
No shortage of Civil Engineers, says SAICE President.
S.A. Construction World, May, pgs 38-41.
- Taylor, J.M. (1980).
Factors Associated with Success in an Engineering Drawing and Design Course.
Special Report No. 314, National Institute for Personnel Research, Council for Scientific and Industrial Research, Johannesburg, South Africa.
- Taylor, J.M. (1981)
Draft Report on Special EAD Course Undertaken by the Engineering Faculty of the University of the Witwatersrand during 1981.
Unpublished paper, National Institute for Personnel Research, Council for Scientific and Industrial Research, Johannesburg.

- Taylor, J.M. (1983).
Factors Affecting Results of an Engineering Drawing and Design Course: Part Two.
Unpublished paper, National Institute for Personnel Research,
Council for Scientific and Industrial Research, Johannesburg.
- Taylor, J.M. (1983).
The Prediction of Success of Black Engineering Technicians.
Paper presented at Psychological Association of South Africa, 1983
Annual Congress, Pietermaritzburg.
- Van den Berg, J. (1983).
Black Education - A new Perspective.
The South African Mechanical Engineer Vol 33, October.
- van der Merwe, E. (1983).
Report on an Approach to the Teaching of Engineering Analysis and Design.
Working Paper 165, the Undergraduate Cadet Scheme, University of the
Witwatersrand, Johannesburg.
- Vernon, P.E. (1950).
The Structure of Human Abilities.
Greenwood Press Publishers, Westport, Connecticut.
- Whorf, B.L. (1956).
Language Thought and Reality
Cambridge, Massachusetts, Technology Press
- Wilburn, A.Y. (1974).
Careers in Science and Engineering for Black Americans
Science, 184, 4142, 1148 - 1154, June.
- Williams, L.S. (1981).
Educational Opportunities for Blacks in the Sciences, 1955 - 1980:
An Assessment of the Impact of the 1954 Supreme Court Decision.
Negro Educational Review, V32 N1 Pg 101 - 195, January.
- Wilson, B.J. (1972).
Some Aspects of Understanding Visual Symbols.
The Development of Science and Mathematics Concepts in Children.
Bangkok: UNESCO.
- Wittig, M.A. & Sasse, S.H. & Giacomi, J. (1984).
Predictive Validity of Five Cognitive Skills Tests Among Women
Receiving Engineering Training.
Journal of Research in Science Teaching Vol 21, No. 5, pgs 537-546.
- Worsnop, J. (1975).
An Investigation into the Possible Remedial Effect of Stereoscopic Projection in the field of Pictorial Depth Perception.
Unpublished M.Sc. Dissertation, University of East Anglia.

APPENDIX ONE

UCT SPATIAL BATTERY

I ROTATION AND VISUALIZATION IN THREE DIMENSIONS

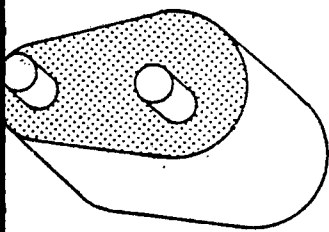
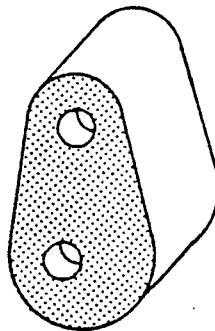
Each of the following eight items consists of a block with an opening or openings and five other blocks with projecting points.

From the alternative blocks in each item chose the one whose projecting point or points fit exactly into the block with the opening or openings.

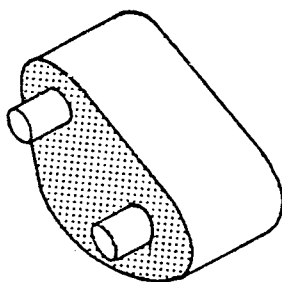
In each item there is only one block which fits.

Example

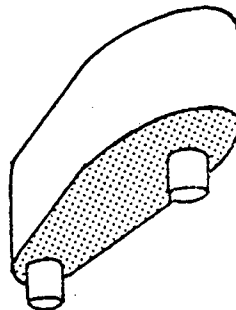
() a.



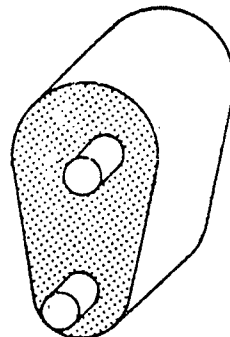
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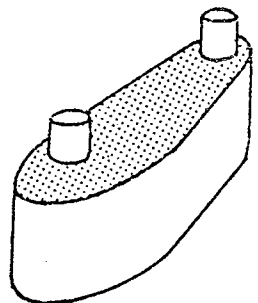
B.



C.



D.



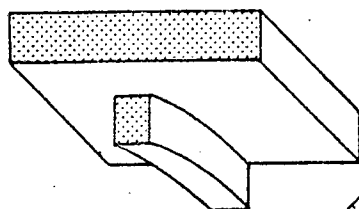
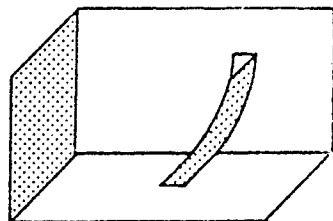
E.

Block B is the only one that fits exactly on the block with the openings in such a way that the projecting points fit into the openings. You would write "B" in the brackets in front of a, thus: (**B**) a.

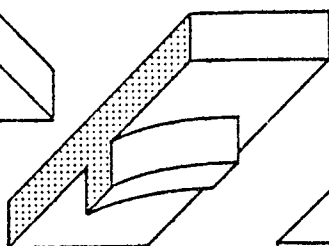
Attempt an answer to every question, even if sometimes you have to guess.

() 1.

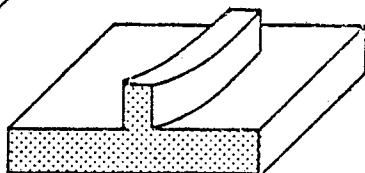
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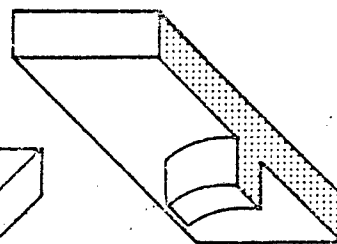
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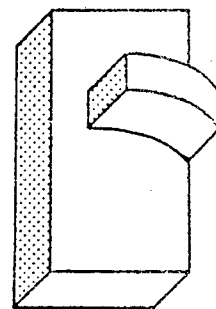
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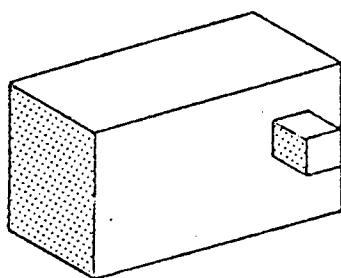
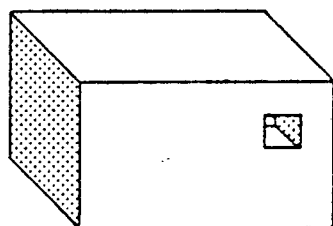


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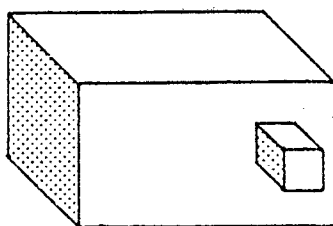


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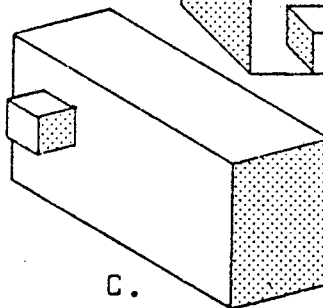
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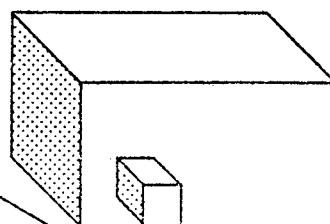
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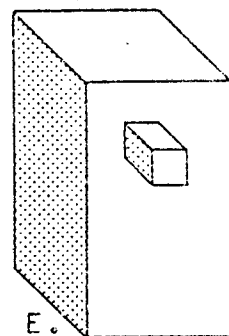
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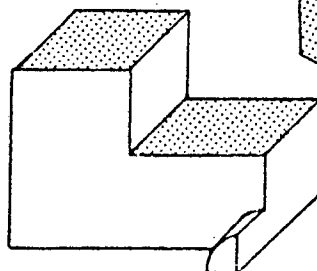
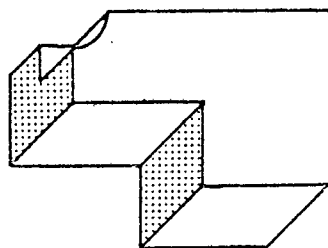


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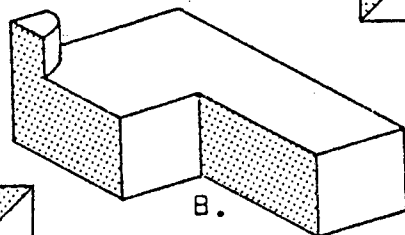


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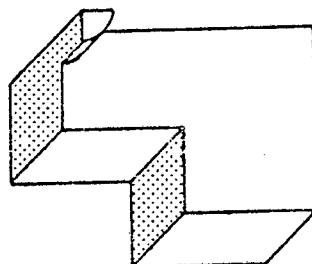
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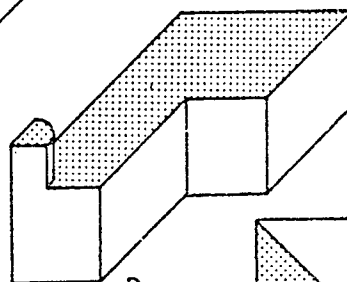
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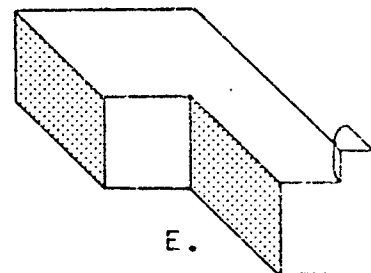
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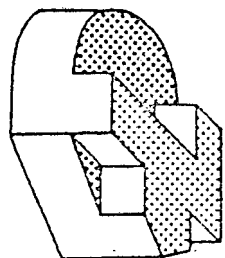
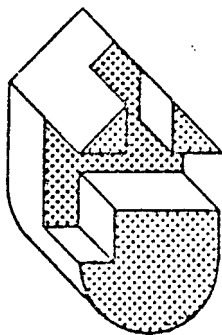
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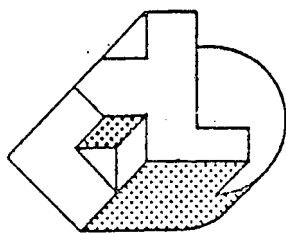
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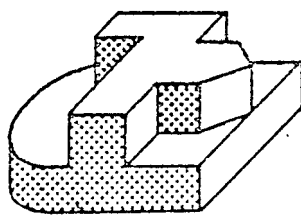
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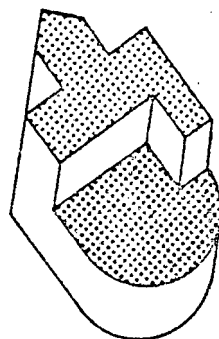
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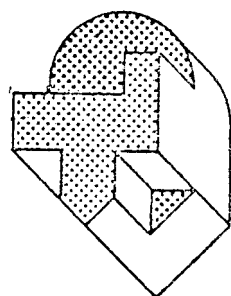
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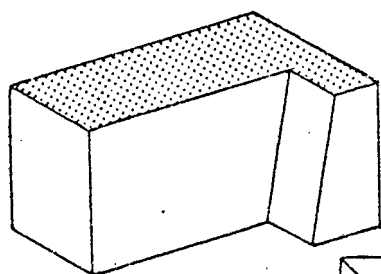
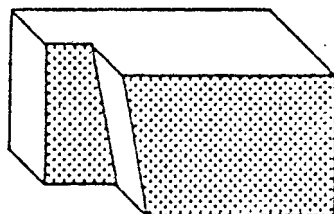


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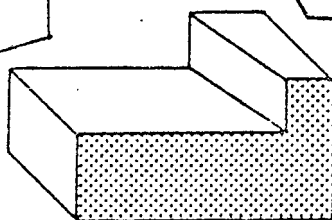


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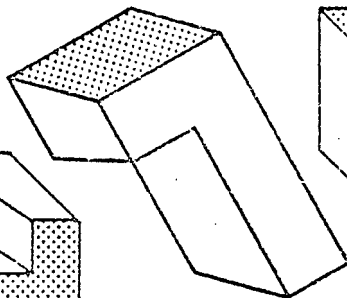
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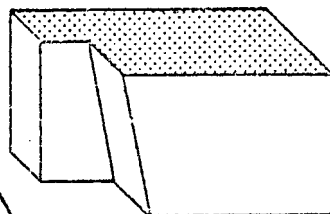
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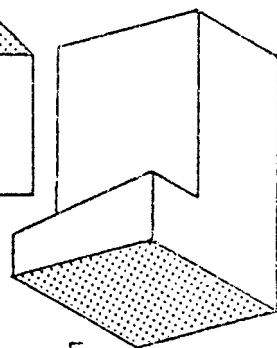
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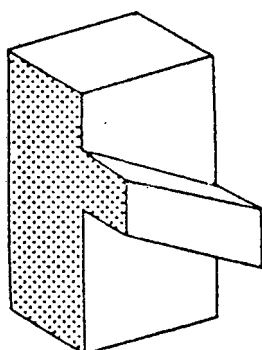
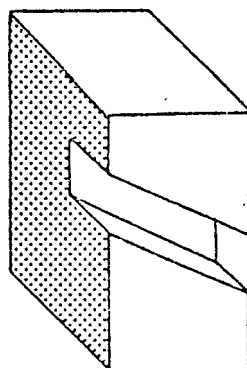


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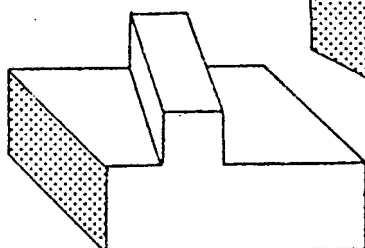


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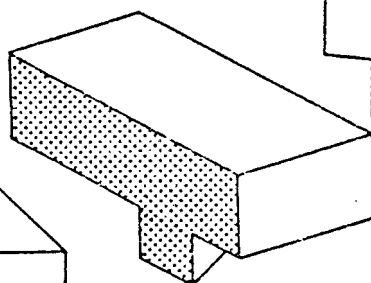
() 6.



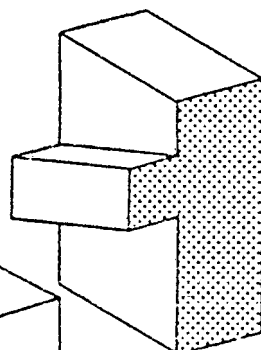
A.



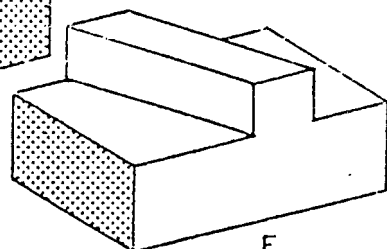
B.



C.



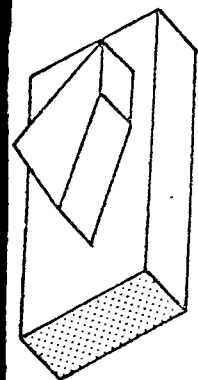
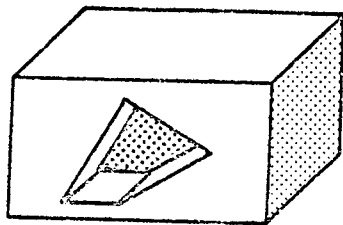
D.



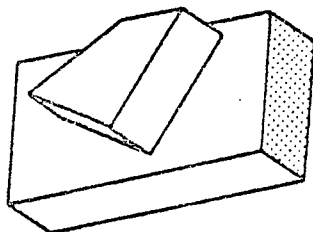
E.

7. ()

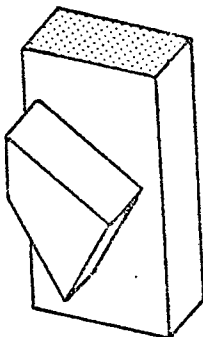
1.5



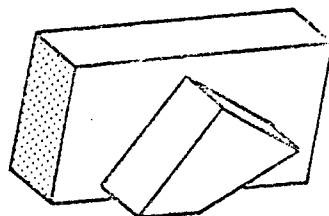
A.



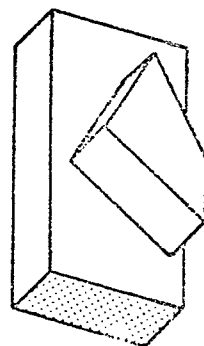
B.



C.

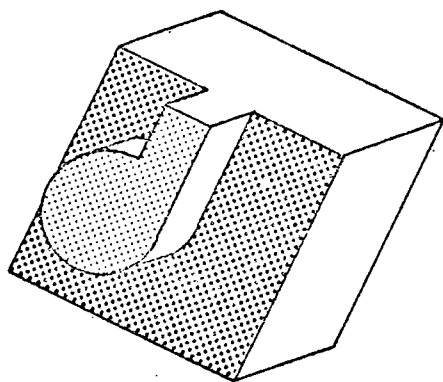
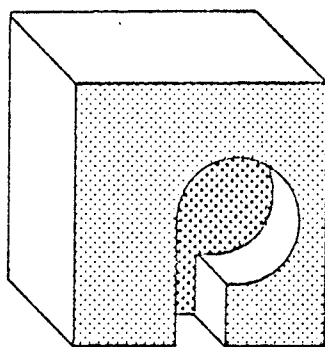


D.

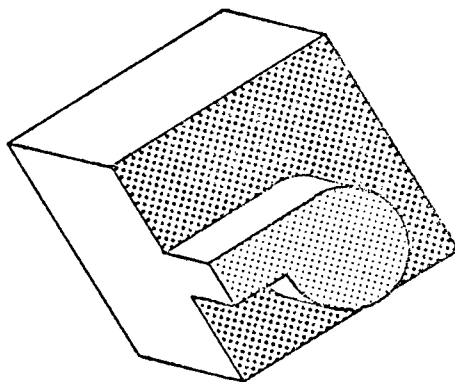


E.

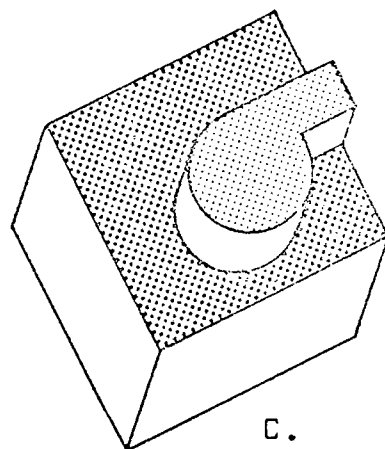
8. ()



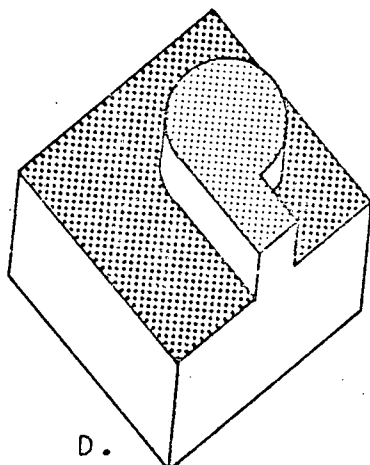
A.



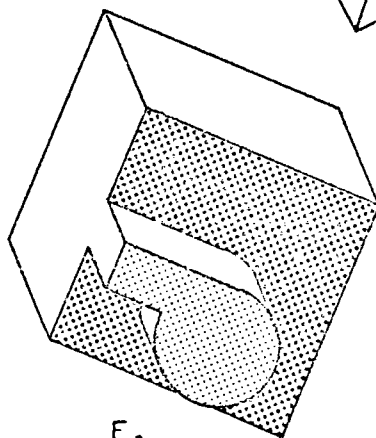
B.



C.



D.



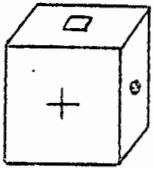
E.

II ROTATION OF CUBES

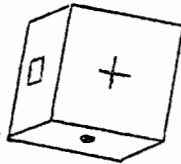
Find the one cube that does not belong with the other four, and write your answer inside the brackets in front of the number of each item.

The cubes may be rotated or turned over in any direction. In every case four of the five cubes are identical. Name the odd one out.

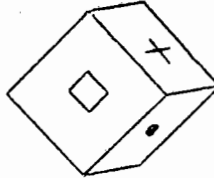
) 1.



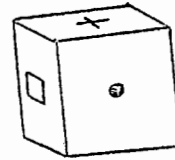
A



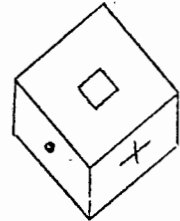
B



C

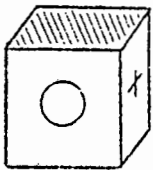


D

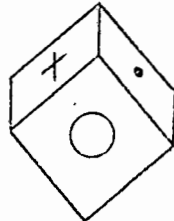


E

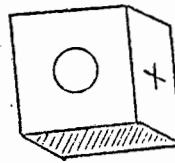
) 2.



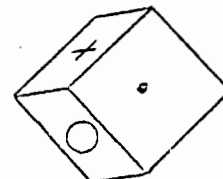
A



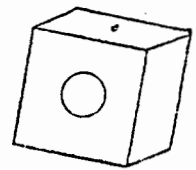
B



C

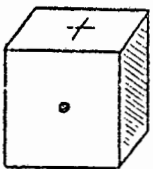


D

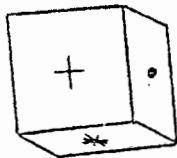


E

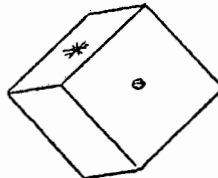
) 3.



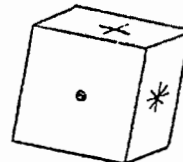
A



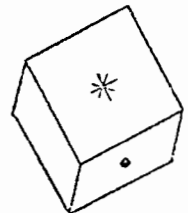
B



C

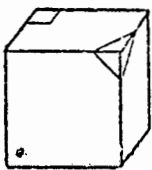


D

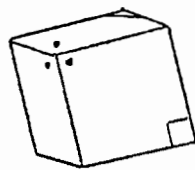


E

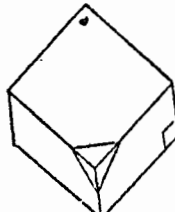
) 4.



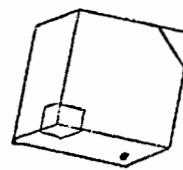
A



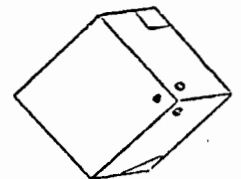
B



C

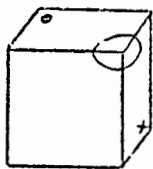


D

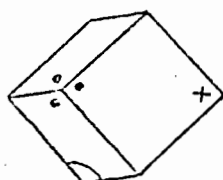


E

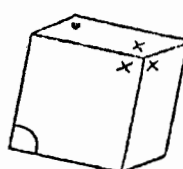
) 5.



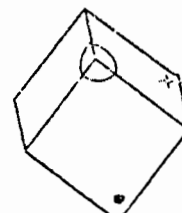
A



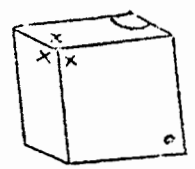
B



C



D



E

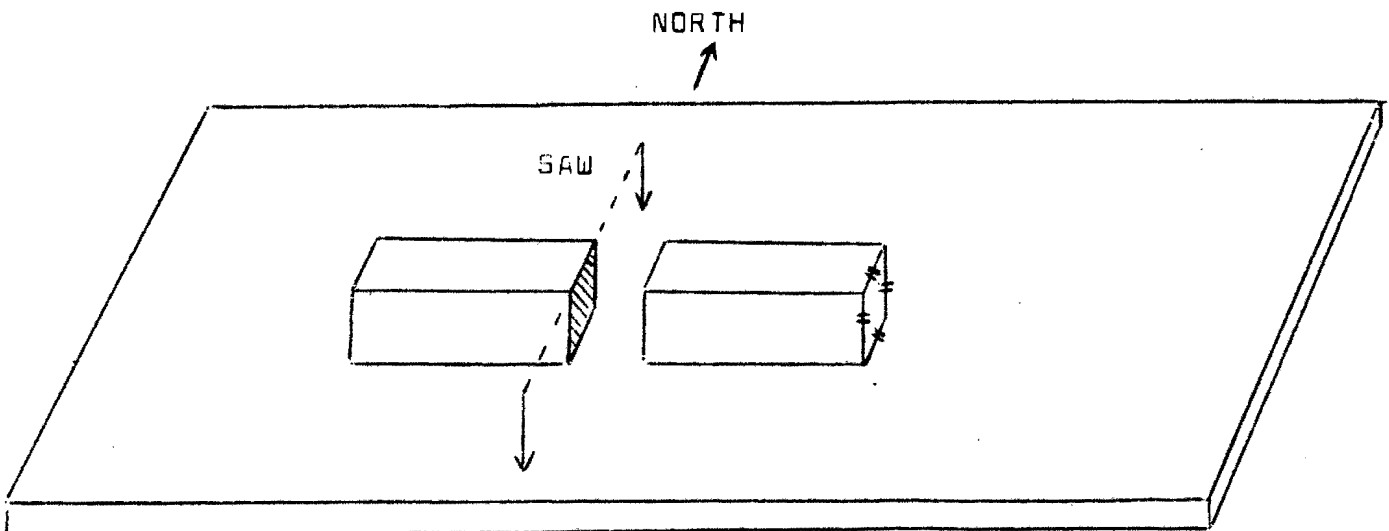
NAME : _____

III SPATIAL SYNTHESIS TEST

When any object, such as a brick, is placed on a table, it can be cut into two parts in many ways. In this test we will make only three different cuts which we will call (i) a north-south vertical cut; (ii) an east-west vertical cut; and (iii) a horizontal cut.

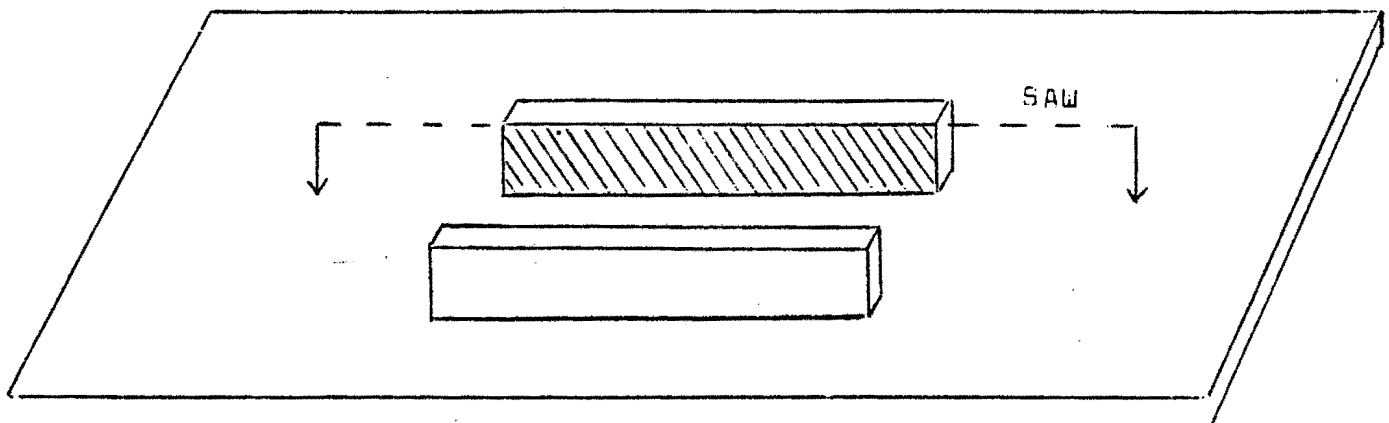
Suppose, for example, we wish to saw in half a long block of wood which has two square ends:-

(i) The north-south vertical cut



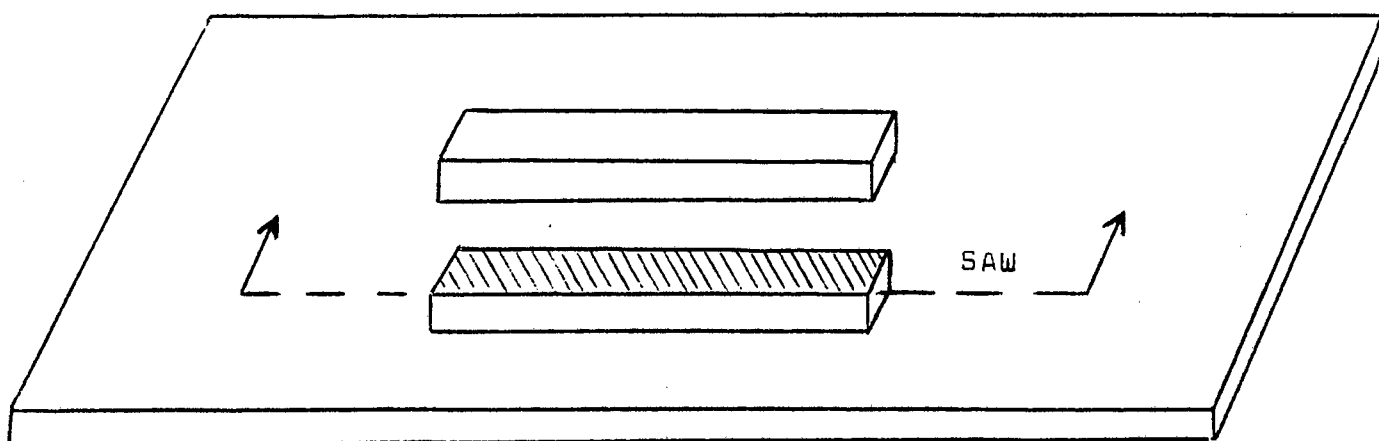
In the above diagram the block has been sawn in half by a north-south vertical cut. The shaded section indicates the newly-sawn face of the wood, and is, in fact, a square.

(ii) The east-west vertical cut



In the preceding diagram the original block has been sawn in half by an east-west vertical cut. The shaded section indicates the newly-sawn face of the wood, and is a rectangle.

(iii) The horizontal cut





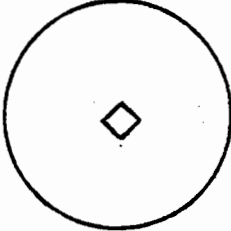
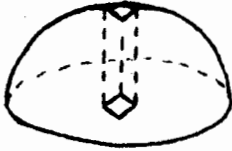
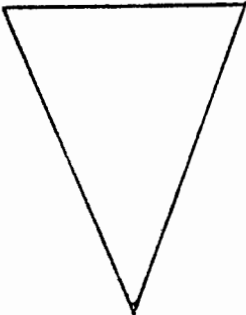
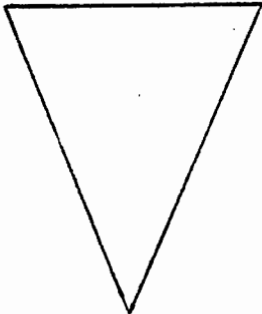
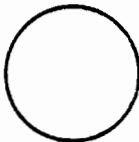



In the above diagram the original block has been sawn in half by a horizontal cut. The shaded section indicates the newly-sawn face of the wood, and, in this case, is also a rectangle.


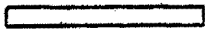
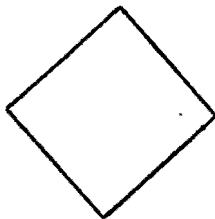
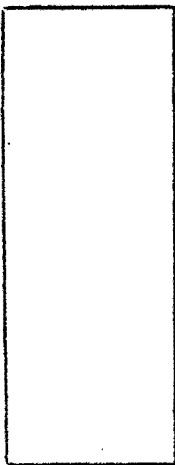
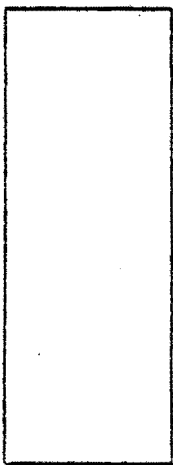
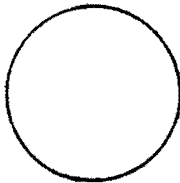
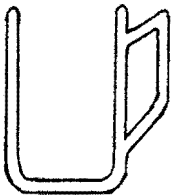
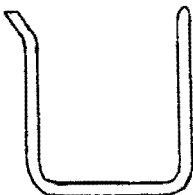
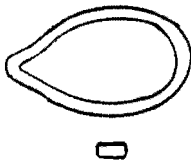
In the following items you are given diagrams of the north-south vertical section, the east-west vertical section and the horizontal section through a three-dimensional object. You are required to deduce the shape of the whole object from its three sections, and to sketch it in the empty space alongside its sections.

There is only one answer per item, i.e. one three-dimensional object deduced from the three two-dimensional sections drawn. If you make a mistake with your sketch, draw your improved sketch on the back of this page, and number the item appropriately.

Finally, describe each object in words by giving it a label or name, e.g.

"a square-based pyramid."

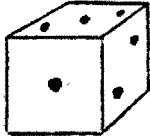

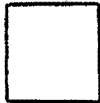

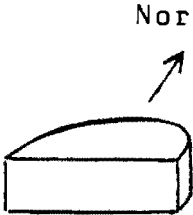

	NORTH-SOUTH VERTICAL SECTION	EAST-WEST VERTICAL SECTION	HORIZONTAL SECTION	ANSWER
EXAMPLE				 <p>A solid hemisphere with a square hole through its axis.</p>
1				
2				

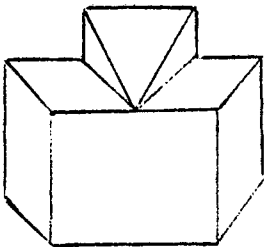
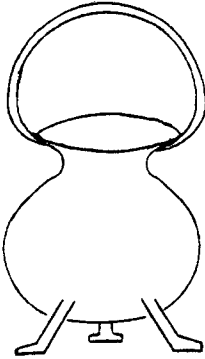

	NORTH-SOUTH VERTICAL SECTION	EAST-WEST VERTICAL SECTION	HORIZONTAL SECTION	ANSWER
3				
4				
5				

NAME : _____

IV SECTIONING TEST

The five objects given below are to be viewed when sectioned in three planes at right angles to each other, as described in the previous test. For each section begin with the original object, slice it in the plane indicated, and sketch the appearance of the resulting two-dimensional section.

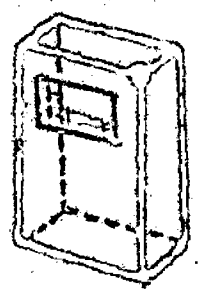
	OBJECT	NORTH-SOUTH VERTICAL SECTION	EAST-WEST VERTICAL SECTION	HORIZONTAL SECTION
EXAMPLE	DICE 			
1	A SEMI-CIRCULAR PRISM North 			
2	A HORIZONTAL PENCIL, OF HEXAGONAL CROSS- SECTION, WHOSE TIP POINTS NORTH North 			

	OBJECT	NORTH-SOUTH VERTICAL SECTION	EAST-WEST VERTICAL SECTION	HORIZONTAL SECTION
3	<p>North ↑</p> 			
4	<p>COOKING POT</p> 			
5	<p>A COIL OR SPIRAL STRETCHED VERTICALLY</p> 			

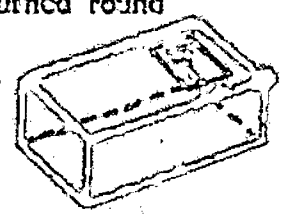
SPATIAL TEST

SPATIAL

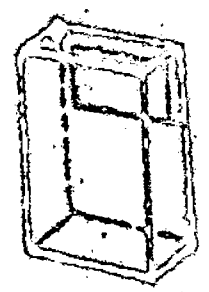
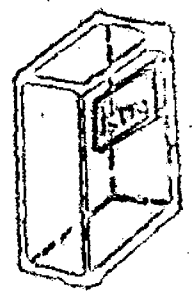
Box with a
black spot in one corner



This is the same box
turned round



It is shown again in three different positions, with the black spot
in the same corner.



GLASGOW SPATIAL BATTERY

Following:-

The left-hand column have a black spot in one corner. Place a
box opposite, so that all five boxes in each row have the
same corner:

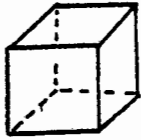
 1	 2	 3	 4
 5	 6	 7	 8
 9	 10	 11	 12

SECTION 2

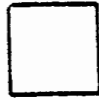
Example:

A model is shown here labelled (a).

How many faces are there in this model equal to the face shown here - labelled (b).



(a)

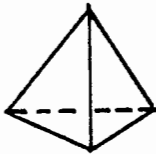


(b)

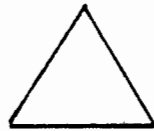
There are six faces, same as (b) in model (a).

Now do the following:

1.



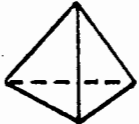
(a)



(b)

How many faces, same as (b) are there in model (a) which is a regular tetrahedron?

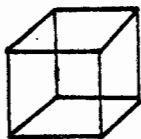
2.



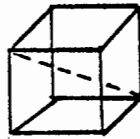
(a)

How many edges of equal length are there in regular tetrahedron (a)?

3.



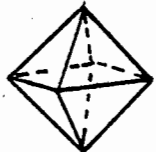
(a)



(b)

How many lines equal in length to dotted line shown in (b), can be drawn in cube (a)?

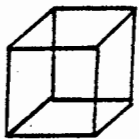
4.



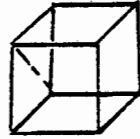
(a)

How many edges of equal length are there in regular octahedron (a)?

5.



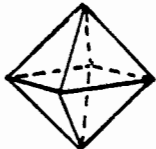
(a)



(b)

How many lines equal in length to dotted line shown in (b) can be drawn in cube (a)?

6.



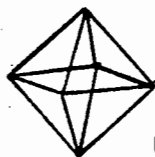
(a)



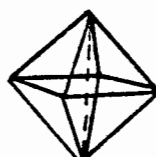
(b)

How many triangular faces equal to (b), are in regular octahedron (a)?

7.



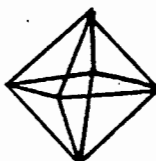
(a)



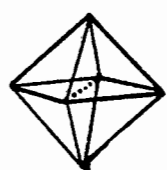
(b)

How many lines equal in length to dotted line shown in (b), can be drawn in regular octahedron (a)?

8.



(a)



(b)

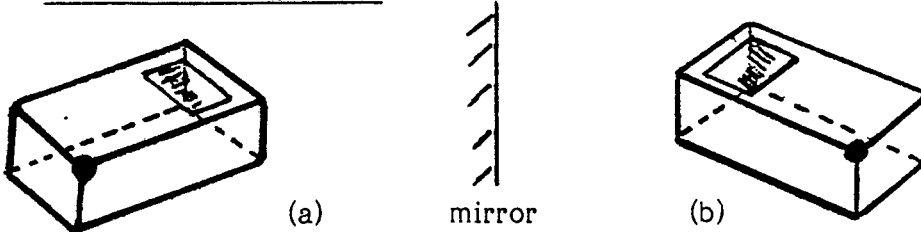
How many lines equal in length to dotted line shown in (b), can be drawn in regular octahedron (a)?

SPATIAL TEST

SECTION 3

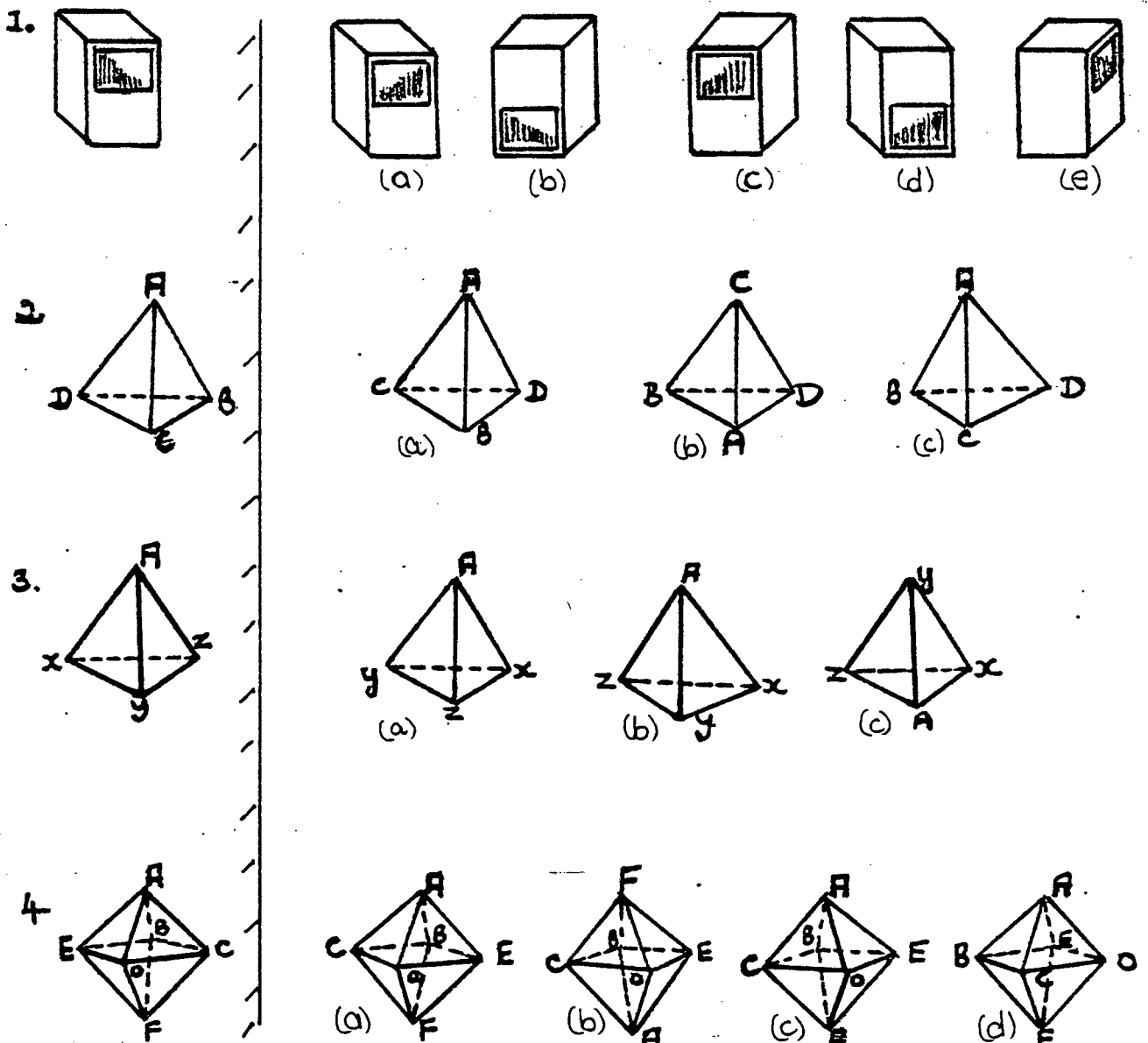
Example:

Taking the centre line to be a mirror, model (b) will be the mirror image of model (a), viewed in that position.



Now do the following:

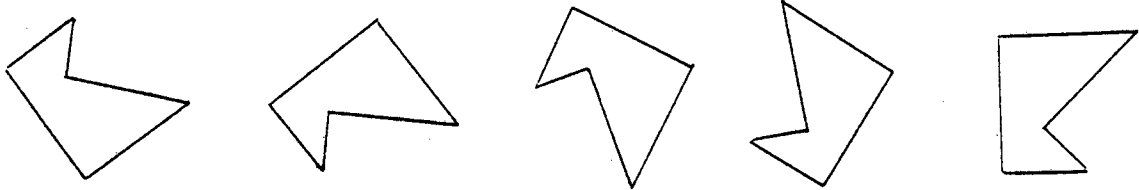
Taking the dividing line to be the mirror, which of the objects opposite will be the mirror image of the object in the left-hand column in that position? Mark your answer on the Answer Sheet provided.



SPATIAL TEST

SECTION 4

Example: On the left-hand side there is the drawing of a shape which, when turned round, on the page, is shown by one of the drawings opposite.

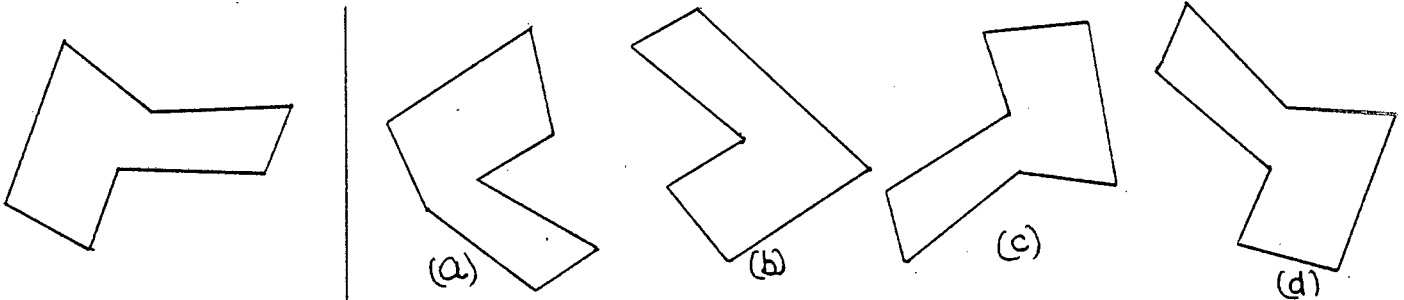


The correct answer is the third drawing, so this one has been ticked.

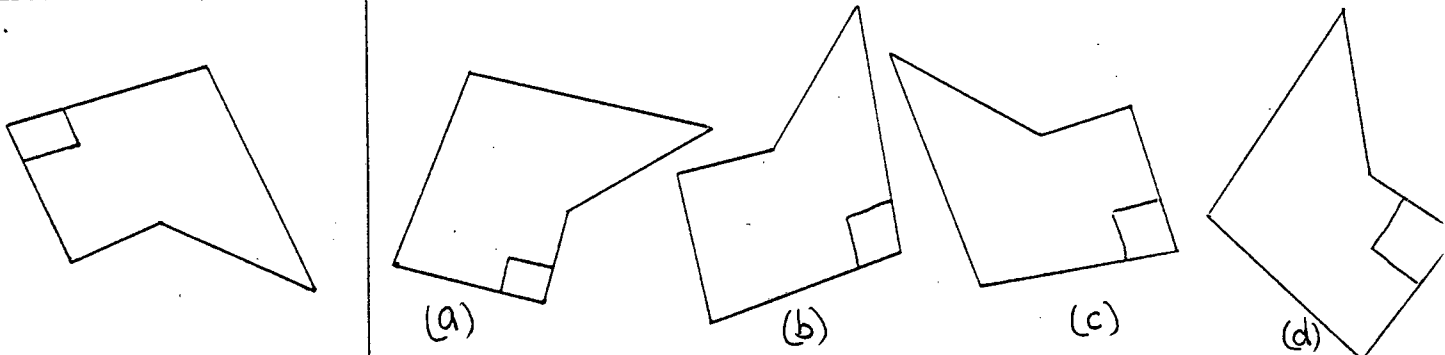
Now do the following:

The drawing on the left-hand side has been turned round, on the page, and is shown by one of the drawings opposite. Mark your answer on the Answer Sheet provided

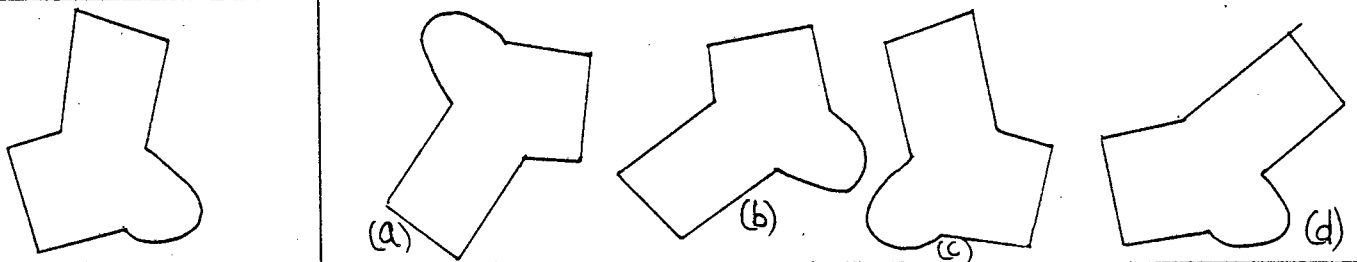
1.



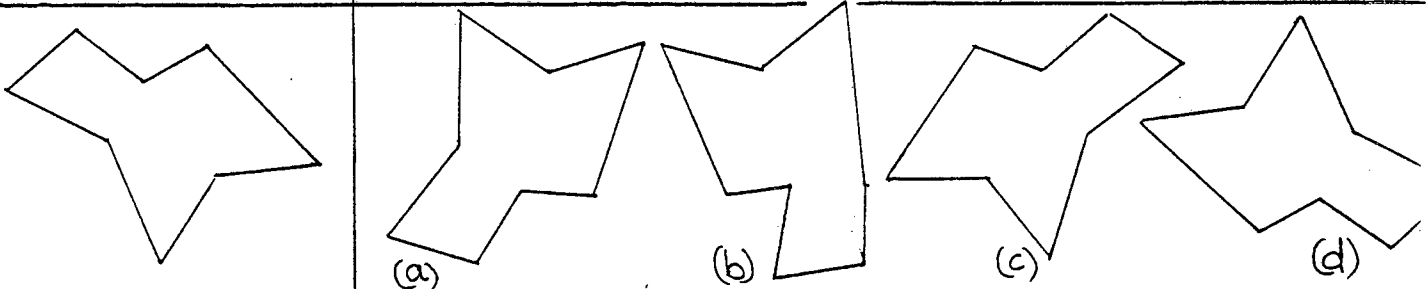
2.



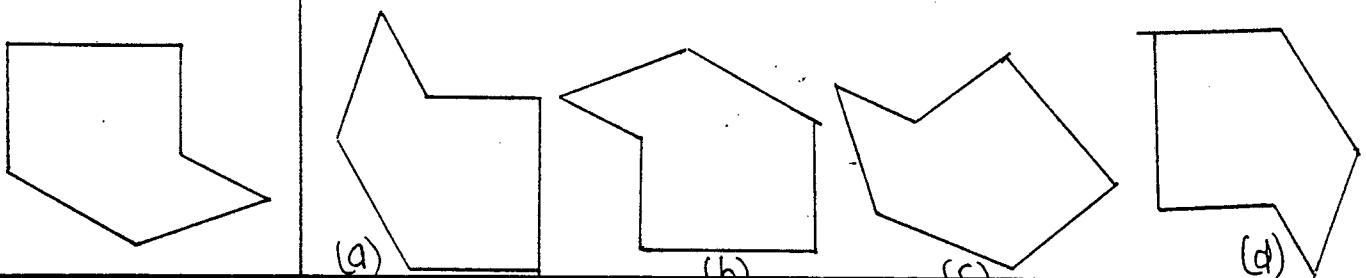
3.



4.



5.



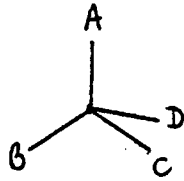
SPATIAL TEST

SECTION 5

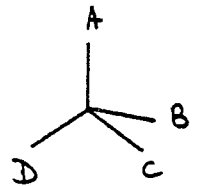
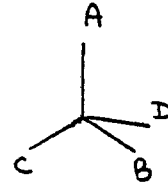
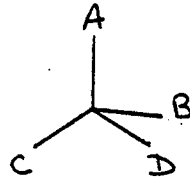
The objects in this section have A, B, C and D in the positions of the four corners of a regular tetrahedron.

In each example, one arm of the model is held, and the model is rotated around that arm.

Example:



Which of the objects below shows model (a) after rotation, with the model being held at A.



Object 1 is the same as (a).

Now do the following:

The objects in the left-hand column are rotated, holding one arm. Which diagram opposite shows that same object after rotation?

Mark your answer on the Answer Sheet provided.

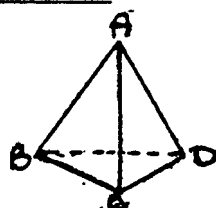
<p>1.</p>	<p>(a)</p>	<p>(b)</p>	<p>(c)</p>
<p>2.</p>	<p>(a)</p>	<p>(b)</p>	<p>(c)</p>
<p>3.</p>	<p>(a)</p>	<p>(b)</p>	<p>(c)</p>

SPATIAL TEST

SECTION 6

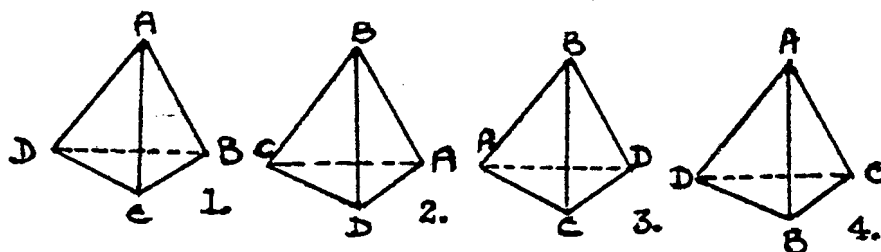
The objects shown in this section are all regular tetrahedra.

Example:



This tetrahedron is rotated in different directions.

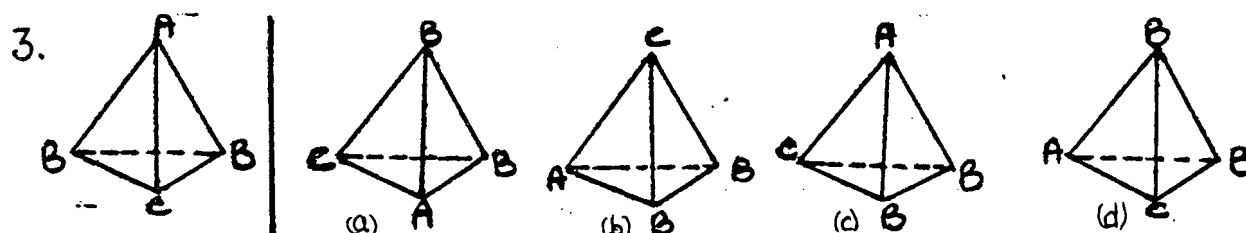
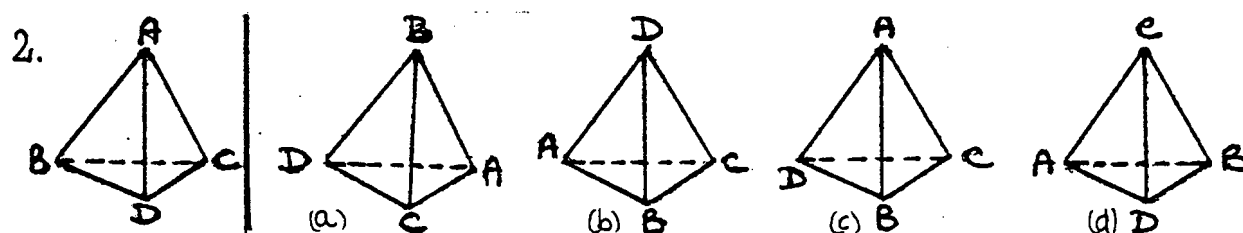
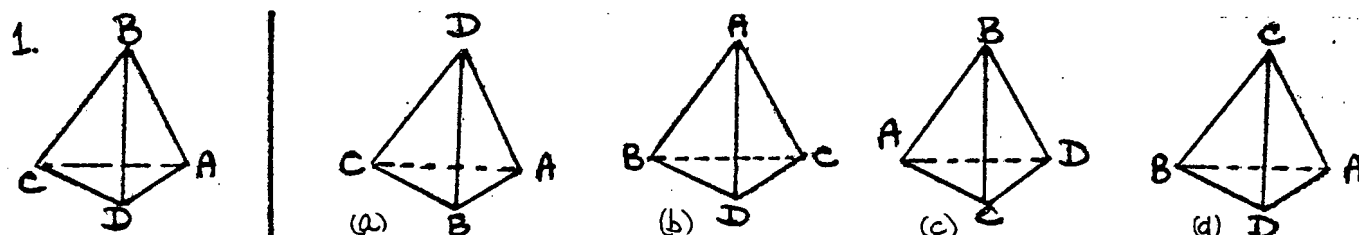
Which one of these tetrahedra shows that same tetrahedron after rotation?



No. 4 is the same tetrahedron.

Now do the following:

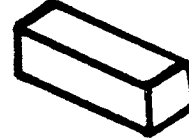
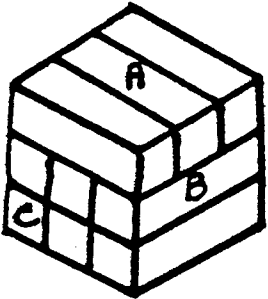
The tetrahedra in the left-hand column are rotated. Which diagram(s) opposite show(s) the same tetrahedron after rotation? Mark your answer on the Answer Sheet provided, there could be more than one correct diagram.



SPATIAL TEST

SECTION 7

Example: In this section the models are made up of blocks of wood. These blocks are all of the same size, as shown. In the model shown here, three of the blocks are marked A, B and C. How many faces of other blocks does each of these lettered blocks touch?



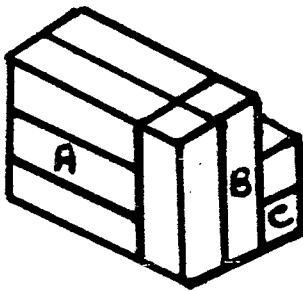
Each block is of the same size.

In this drawing A is touching five blocks; B is touching five blocks; C is touching two blocks.

Now do the following:

In each of the models shown, find out how many blocks A, B and C are touching and write the number in the space provided.

1.

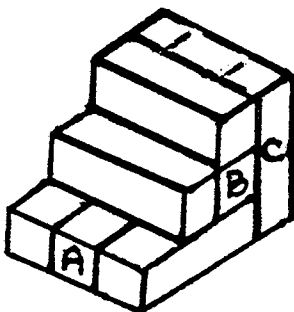


A: _____

B: _____

C: _____

2.



A: _____

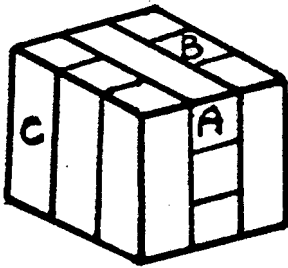
B: _____

C: _____

SPATIAL TEST

SECTION 7 (contd)

3.

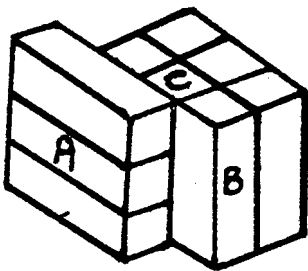


A: _____

B: _____

C: _____

4.

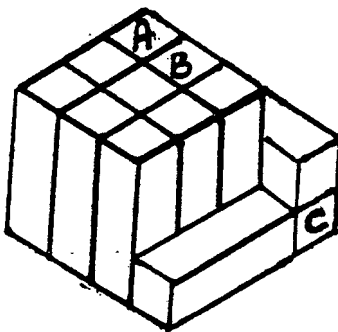


A: _____

B: _____

C: _____

5.



A: _____

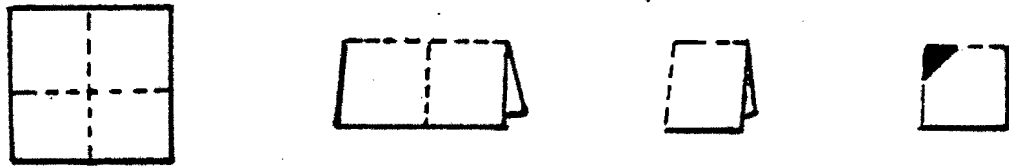
B: _____

C: _____

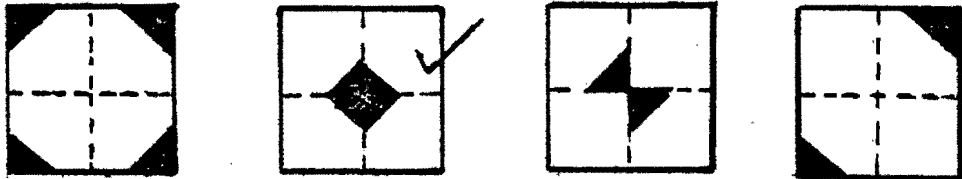
SPATIAL TEST

SECTION 8

Example: A square of paper is folded along dotted lines as shown:



The shaded area is then cut out and the paper unfolded. Which of the following drawings represents how the paper will look when unfolded.



The ticked drawing is the correct one.

Now do the following:

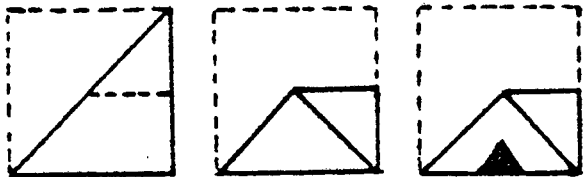
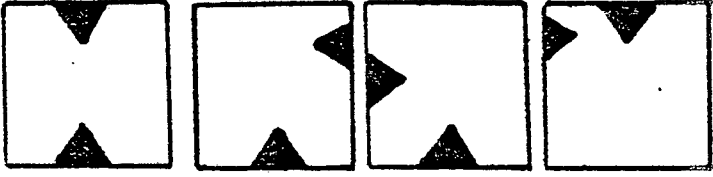
The square of paper is folded along the dotted lines as shown, then the shaded area is cut out. Which of the drawings opposite represents the paper when unfolded? Mark your answer on the Answer Sheet provided.

1.		(a)	(b)	(c)	(d)
2.		(a)	(b)	(c)	(d)
3.		(a)	(b)	(c)	(d)
4.		(a)	(b)	(c)	(d)
5.		(a)	(b)	(c)	(d)

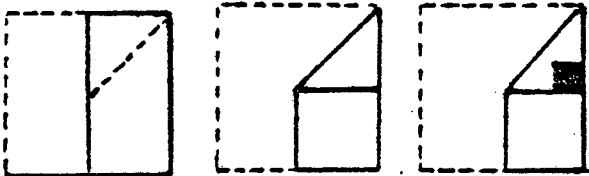
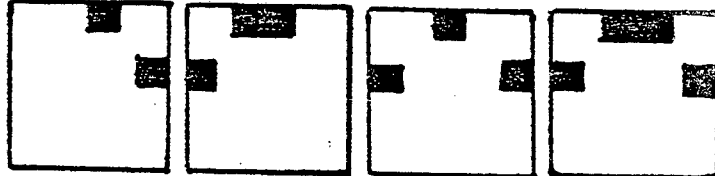
SPATIAL TEST

SECTION 9

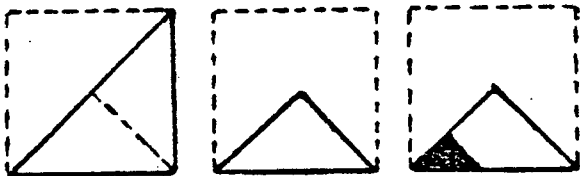

In this section the paper is folded in different ways. On the left-hand side the diagrams show the different stages of paper folding. In the third diagram the shaded area shows the cut out section. After unfolding the square of paper, which diagram on the right-hand side is the correct representation of how it will look? Mark your answer on the Answer Sheet provided.

1.  | 

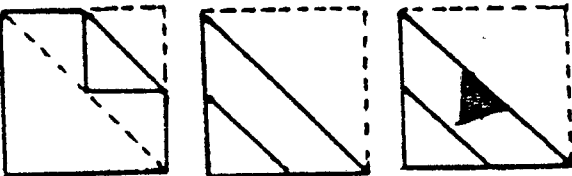

(a) (b) (c) (d)

2.  | 

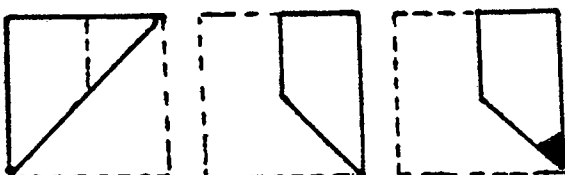
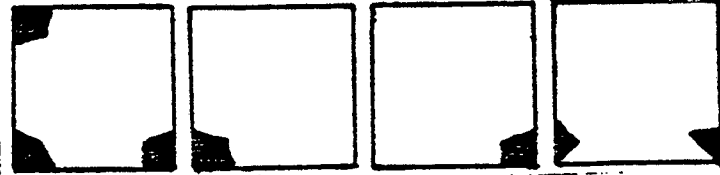
(a) (b) (c) (d)

3.  | 

(a) (b) (c) (d)

4.  | 

(a) (b) (c) (d)

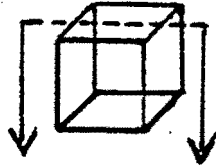
5.  | 

(a) (b) (c) (d)

SPATIAL TEST

SECTION 10

Example: This drawing represents a block of wood which is sawn vertically in two, in the position indicated by the dotted line.



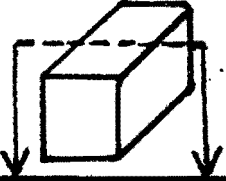




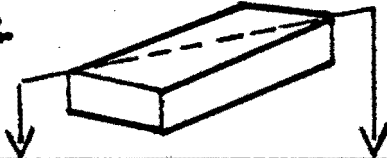


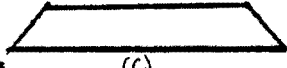

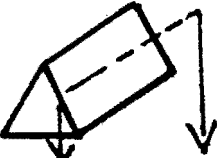


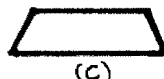

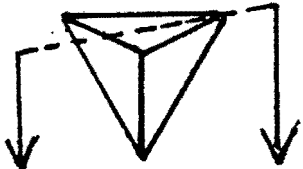
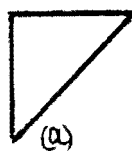
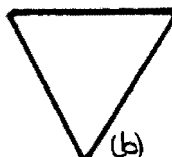
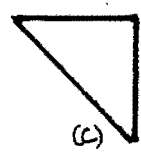
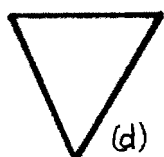
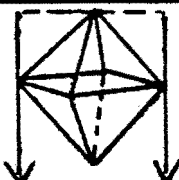
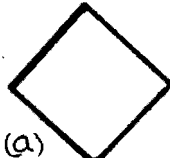

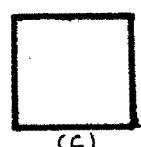
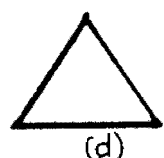
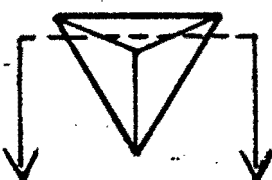


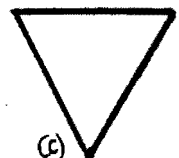

When the two parts of the block of wood are pulled apart, the cut face will be the same shape as one of the following drawings.



The correct shape has been ticked.

Now do the following:

The block of wood in the left-hand column has been sawn in two vertically, as indicated. Which drawing opposite shows the shape of the resulting cut face? Mark your answer on the Answer Sheet provided.

1. 	 (a)  (b)  (c)  (d)
2. 	 (a)  (b)  (c)  (d)
3. 	 (a)  (b)  (c)  (d)
4. 	 (a)  (b)  (c)  (d)
5. 	 (a)  (b)  (c)  (d)
6. 	 (a)  (b)  (c)  (d)

TEST OF PROBLEM SOLVING AND
SPATIAL ABILITY

ACKNOWLEDGEMENTS

C.S.POTTER

E.VAN DER MERWE

UNDERGRADUATE CADET SCHEME

UNIVERSITY OF THE WITWATERSRAND

INSTRUCTIONS

The first two sections invite you to solve problems of a varied nature. You will be provided with rough paper on which to work, but DO NOT draw or make marks in this test booklet.

There are twenty-five problems in this part of the test:

SECTION ONE - 12 problems

SECTION TWO - 13 problems

Each problem is set out on a separate sheet of paper. Your task for each problem is to select the correct answer from the alternatives given and fill it in on the ANSWER SHEET provided. Sections three and four are tests of your spatial ability.

SECTION THREE - 40 problems

SECTION FOUR - 50 problems

Work as quickly and accurately as you can. Indicate your answers in pencil on the ANSWER SHEETS provided.

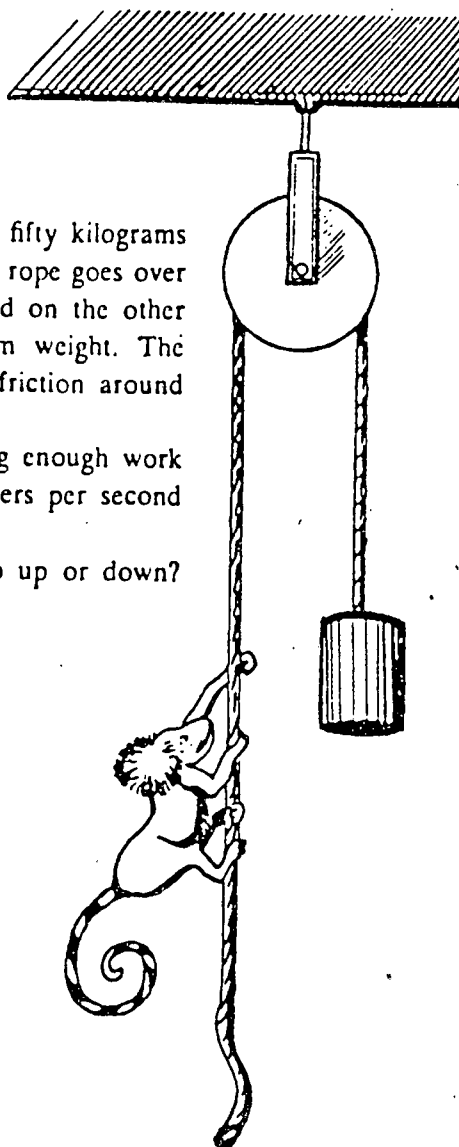
On the next page is an example of the type of problem given in SECTIONS ONE and TWO.

EXAMPLE

A monkey weighing fifty kilograms is climbing a rope. The rope goes over a pulley and is fastened on the other side to a fifty-kilogram weight. The pulley rotates without friction around a fixed axis.

The monkey is doing enough work to climb forty centimeters per second if the rope was fixed.

Does the monkey go up or down?
How fast?



- (a) 40cm per second up
- (b) 20cm per second up
- (c) The monkey stays stationary
- (d) 20cm per second down
- (e) 40cm per second down

The correct answer is given on the following page.

The correct answer is 20cm per second up.

(b) is thus the correct alternative.

Make a cross X in (b) next to the row marked "EXAMPLE" on your ANSWER SHEET

A time limit is imposed :

SECTION ONE	15 MINUTES
SECTION TWO	15 MINUTES
SECTION THREE	5 MINUTES
SECTION FOUR	5 MINUTES

DO NOT GO ON WITH THE NEXT SECTION UNTIL TOLD TO DO SO.

Make sure that you always mark your answer sheet by crossing the correct box next to the number of the question you are answering. If you make a mistake use an eraser to erase the incorrect answer and then put a cross in the correct box to indicate the chosen alternative.

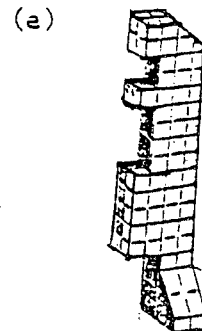
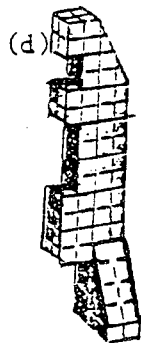
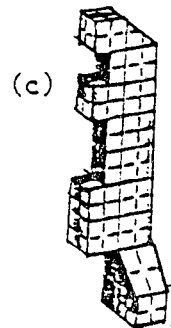
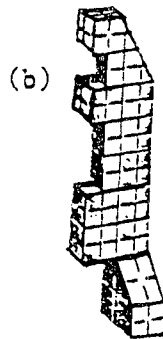
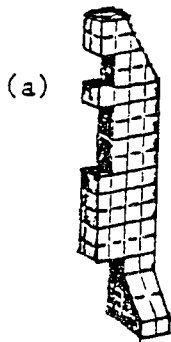
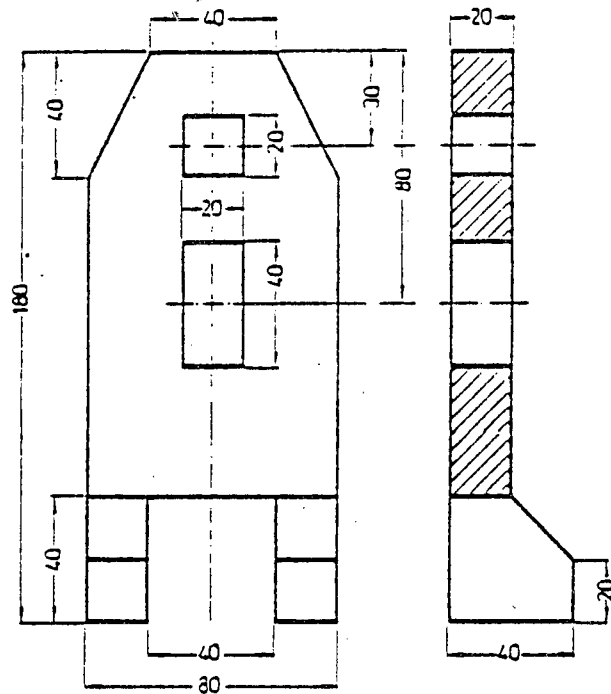
Are there any questions?

Are you ready? You have 15 minutes to do SECTION ONE.

SECTION ONE

15 MINUTES

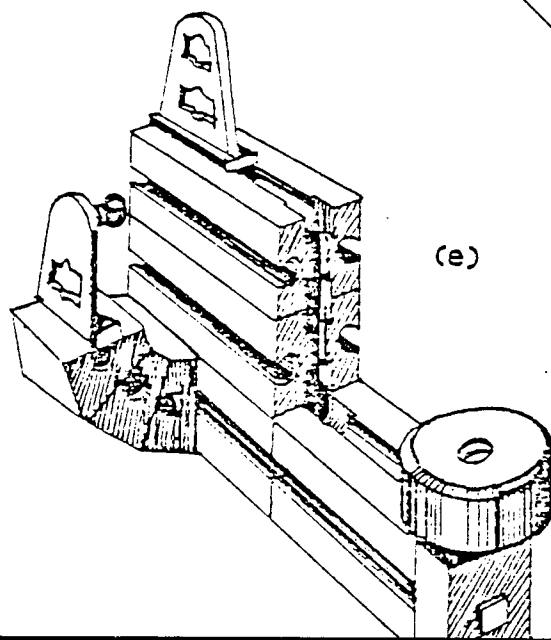
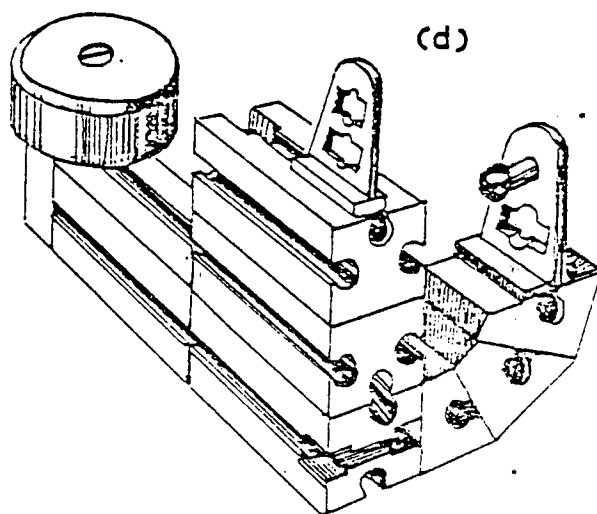
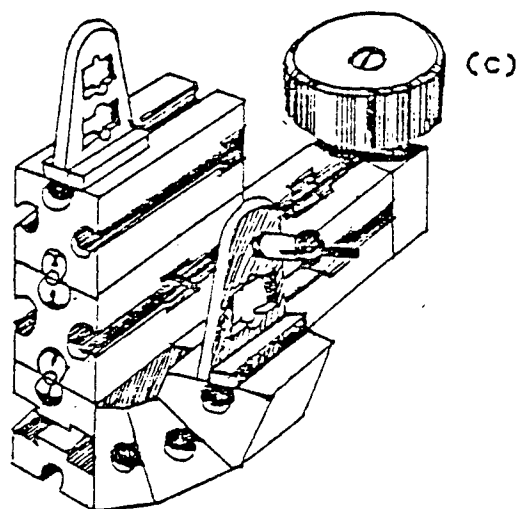
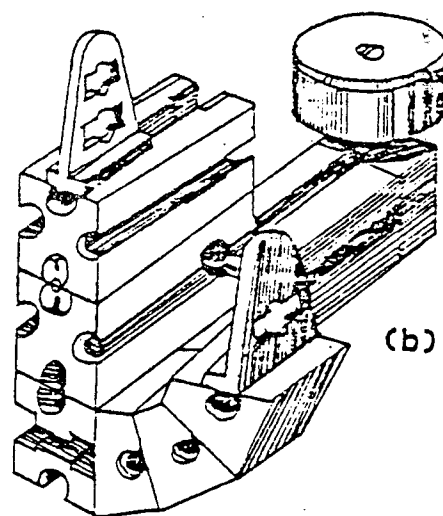
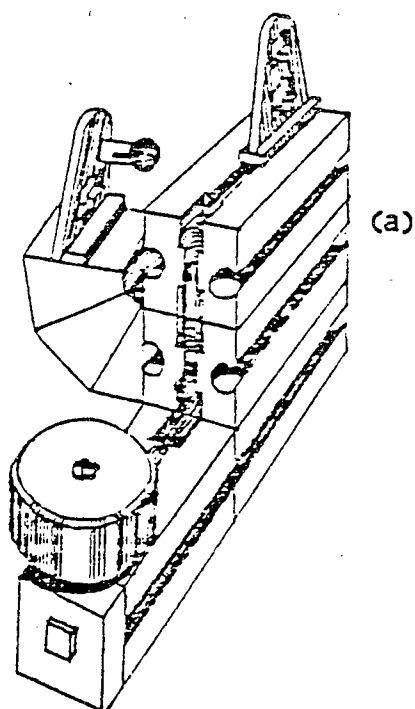
- 1 If only the right-hand half of the model represented in the drawing below must be built, choose the correct model from the five alternatives.



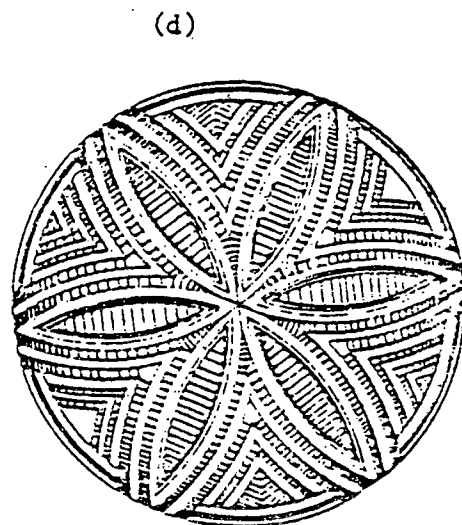
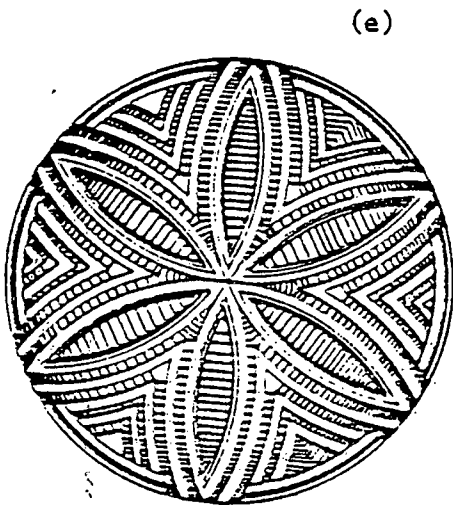
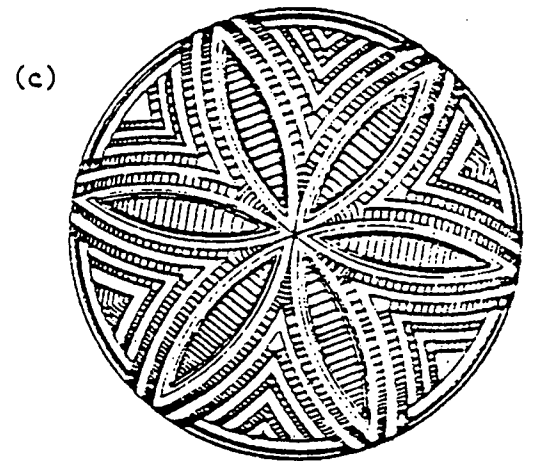
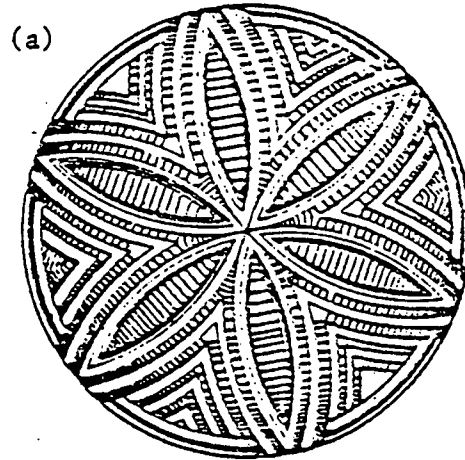
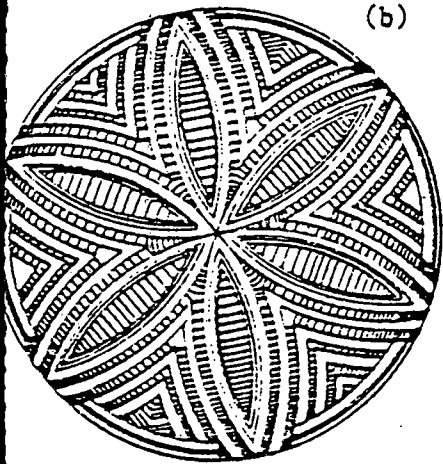
2

Five constructions are given.

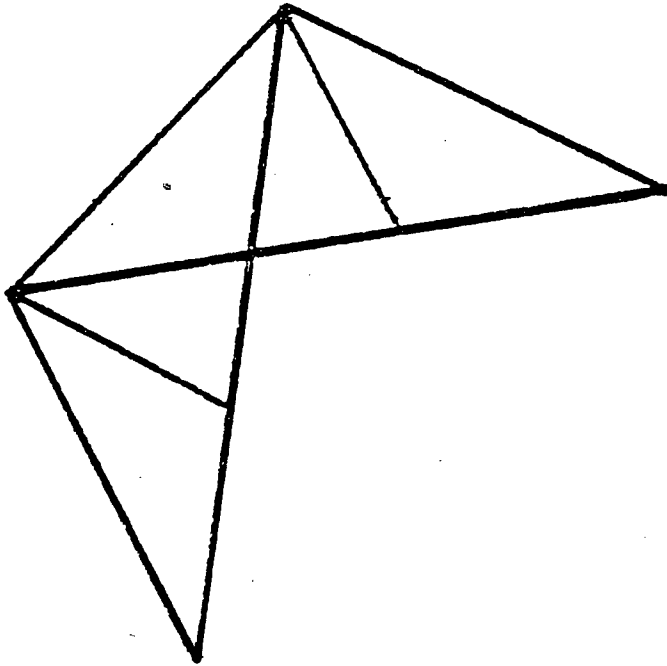
One is not the same - which one?



- 3 One drawing is different from the others.
Which one is it?

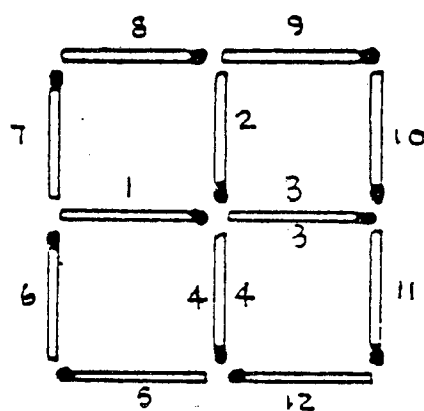


- 4 How many triangles are there in the diagram?
Can you count them methodically enough not
to miss any?



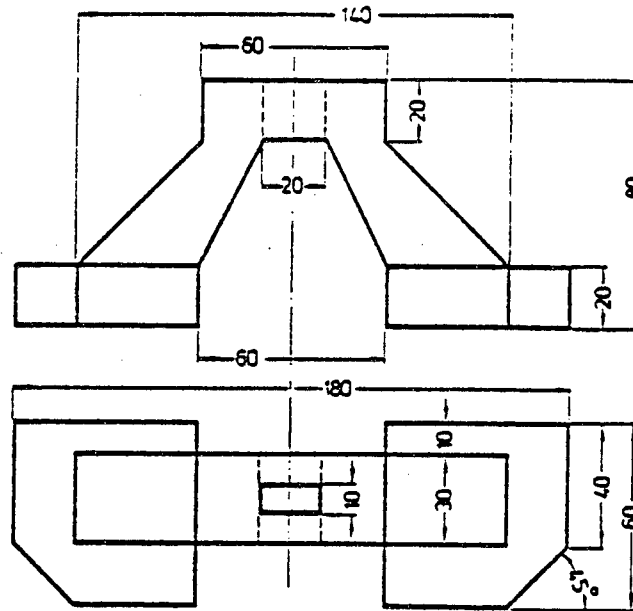
- (a) 9
- (b) 10
- (c) 8
- (d) 12
- (e) 11

- 5 Which two matches should you remove so that only two squares are left?

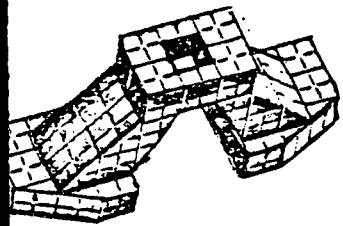


- (a) 7 and 8
- (b) 2 and 10
- (c) 1 and 6
- (d) 1 and 2
- (e) 1 and 3

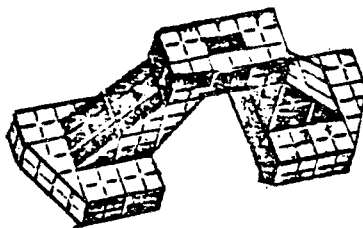
- 6 Two views of a model are represented below.
Choose the correct model from the five alternatives.



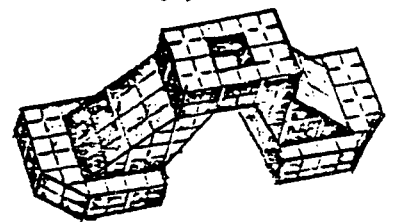
(a)



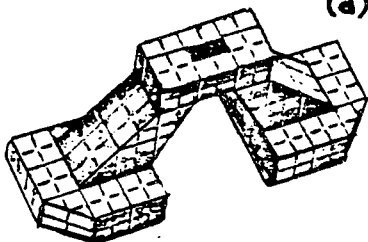
(b)



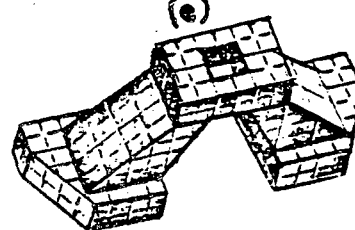
(c)



(d)

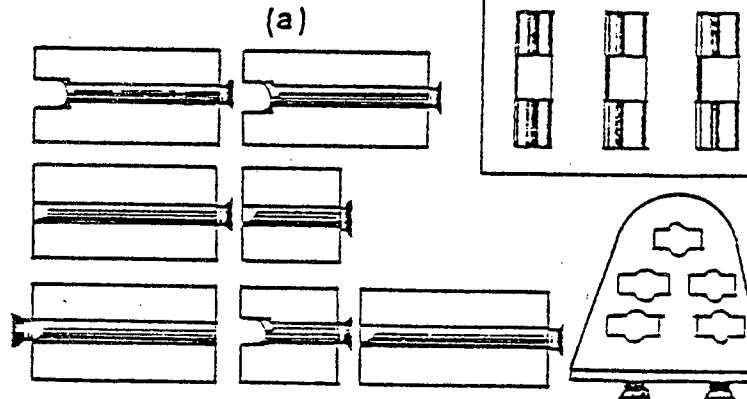
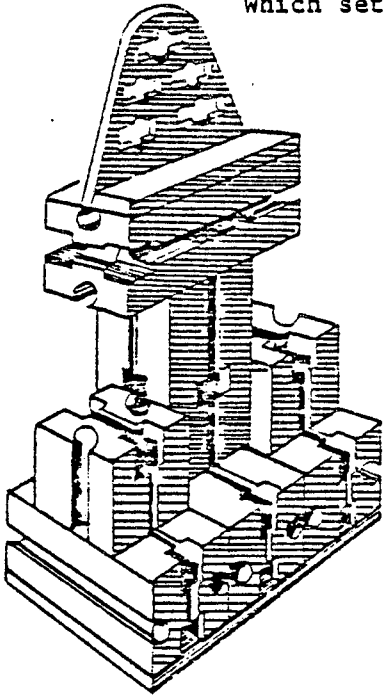


(e)

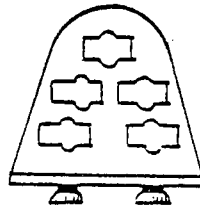
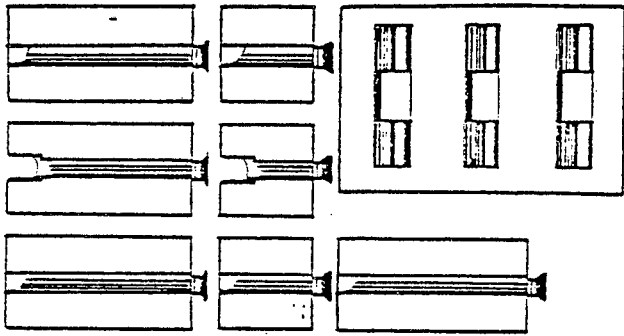


7

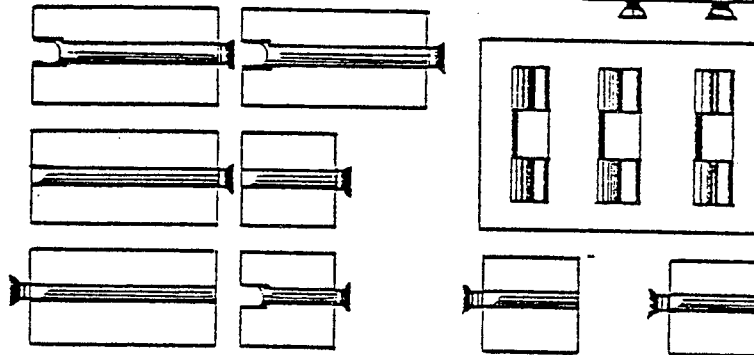
Which set of components will give the following model?



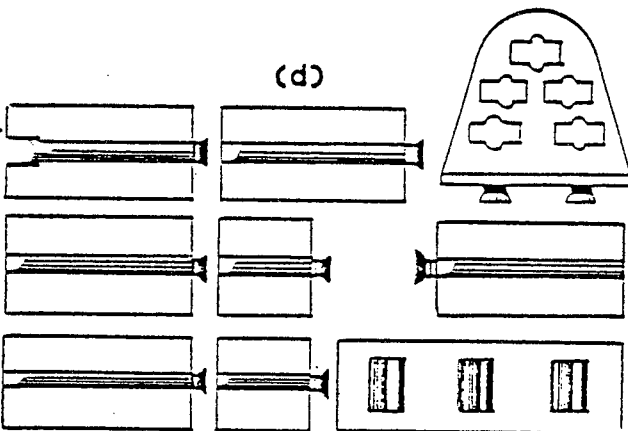
(b)



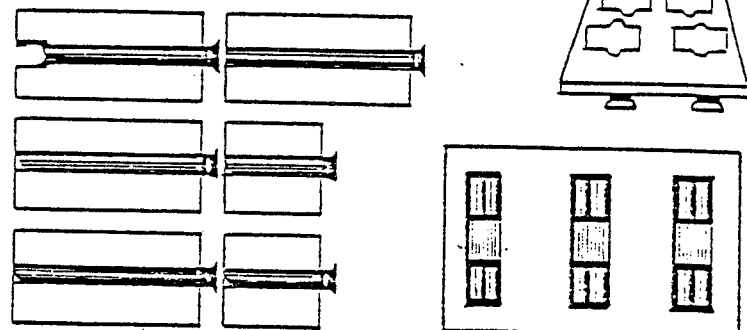
(c)



(d)



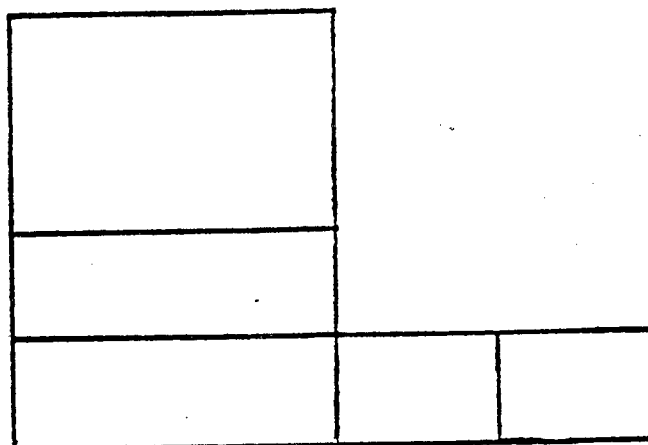
(e)



8

How many rectangles are there in the diagram?

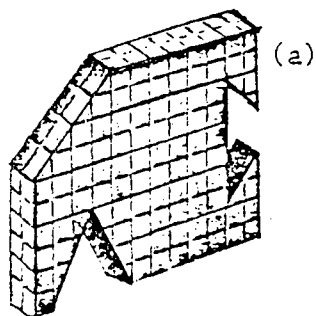
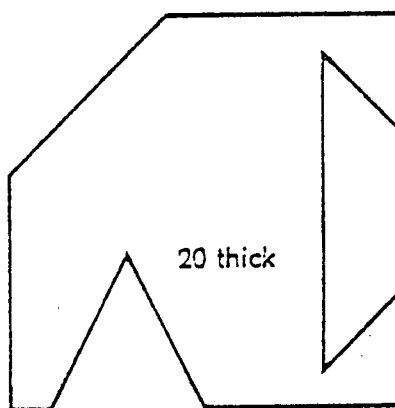
(Note: A square is a rectangle)



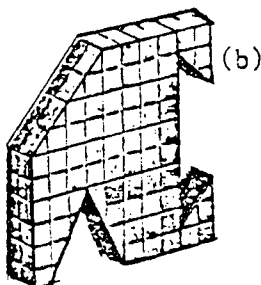
- (a) 10
- (b) 8
- (c) 9
- (d) 11
- (e) 12

9

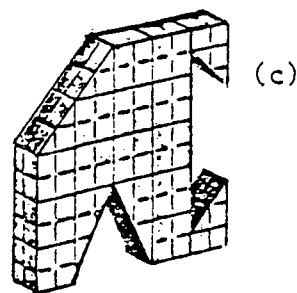
Which model is represented in the following drawing?



(a)

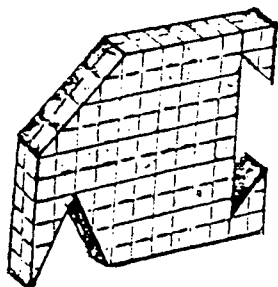


(b)

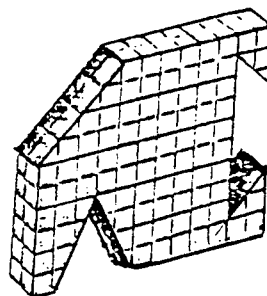


(c)

(d)



(e)

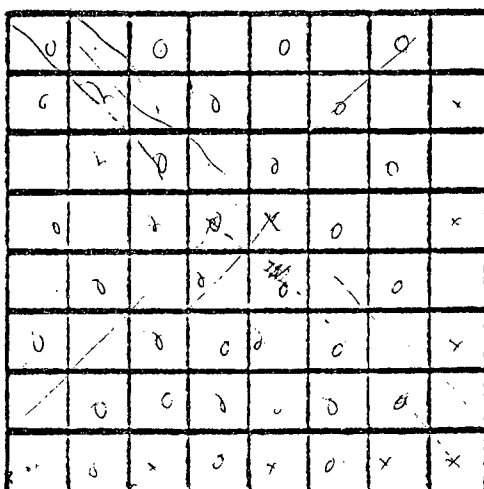


10

How many bishops do you have to place on a chessboard so that each square is:

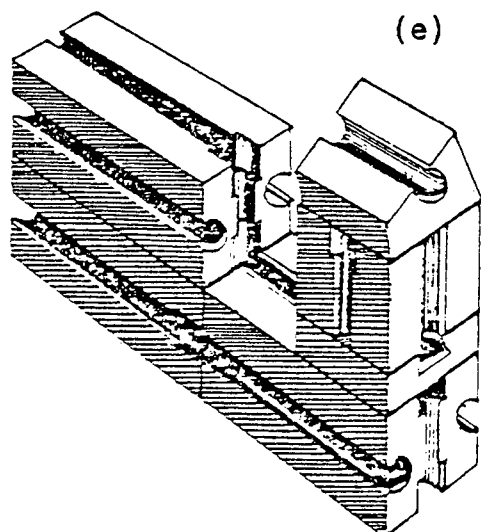
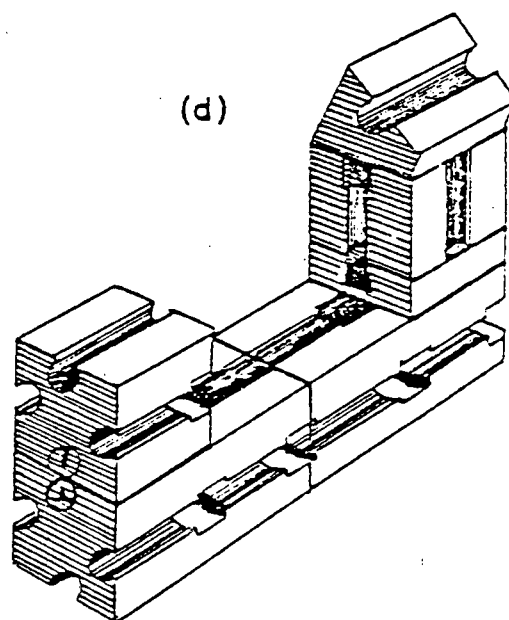
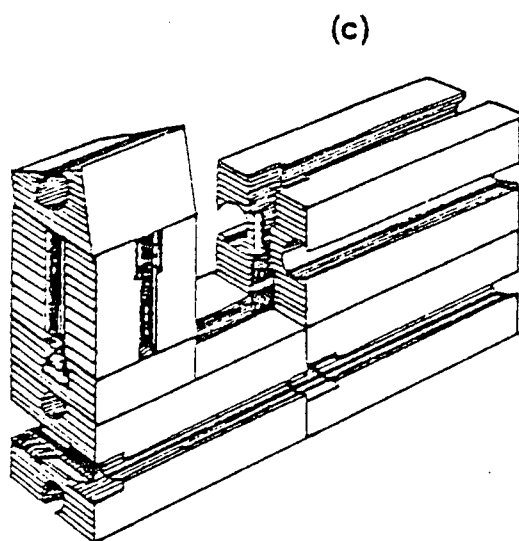
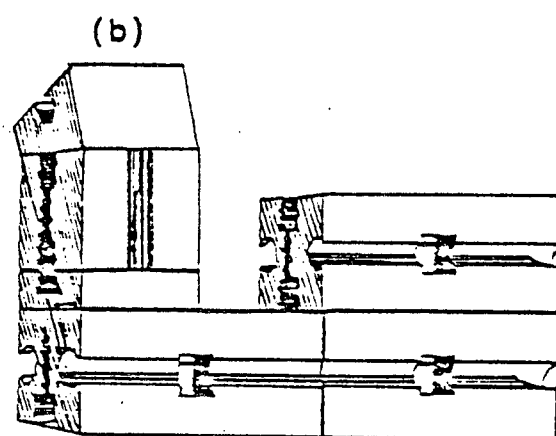
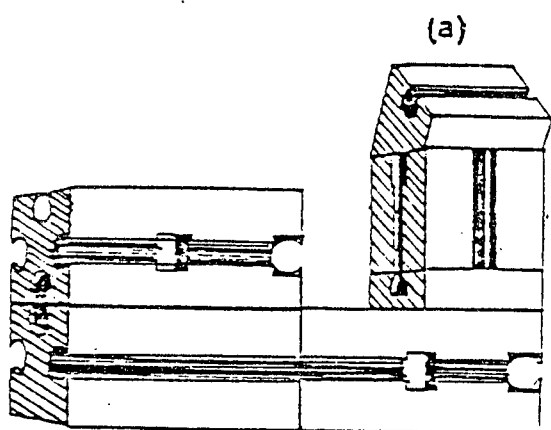
- occupied by a bishop
- or threatened by at least one bishop ?

(A bishop can move any number of squares diagonally)



- (a) 6
- (b) 9
- (c) 7
- (d) 8
- (e) 10

- 11 Five constructions are given.
One is not the same -which one?

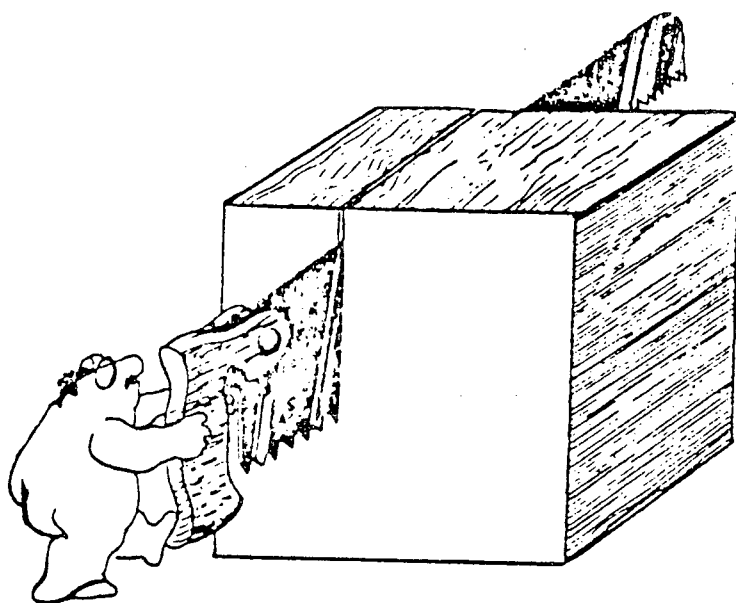


12

Timothy wants to saw a cube of wood into twenty-seven equal cubes.

During the work, if several pieces are already sawed, he can arrange them as he pleases, then saw through all of them with one cut.

Working this way, how many operations are needed?



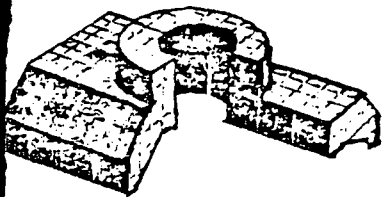
- (a) 5
- (b) 9
- (c) 6
- (d) 7
- (e) 10

STOP

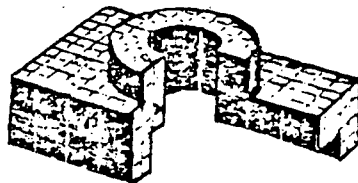
WAIT FOR FURTHER INSTRUCTIONS

- 1 A quarter section is removed from the model. Which model has been drawn below?

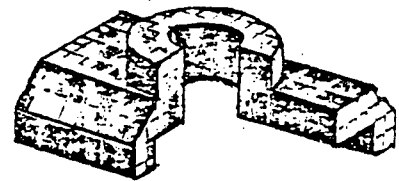
(a)



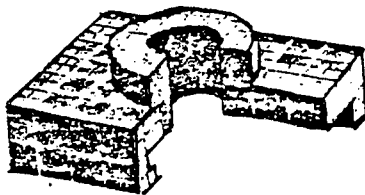
(b)



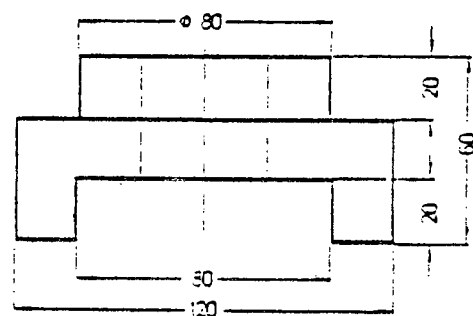
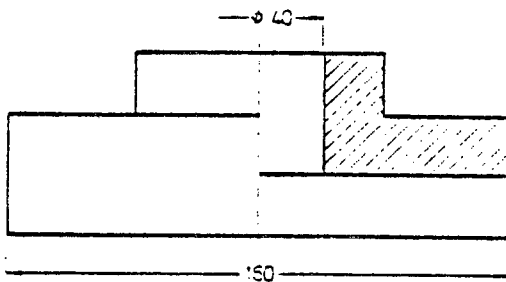
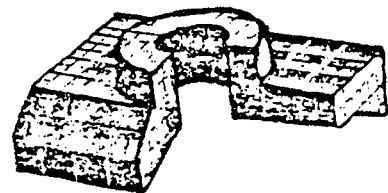
(c)



(d)



(e)

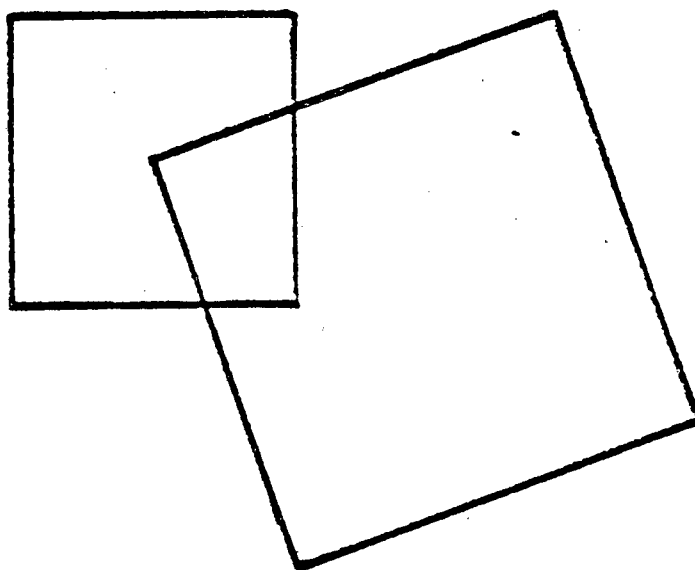


- 2 The side of the small square is one metre and the side of the large square one and a half metres.

One vertex of the large square is at the centre of the small square.

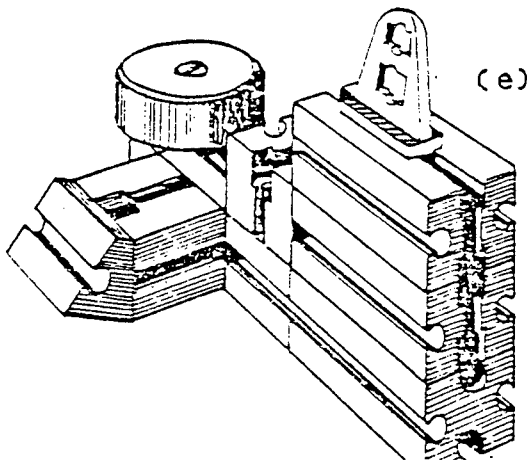
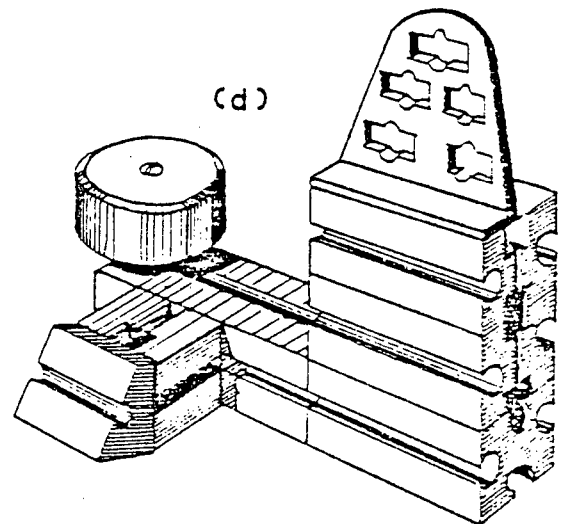
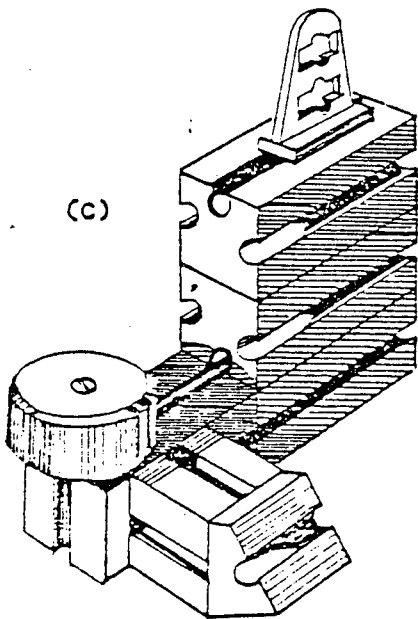
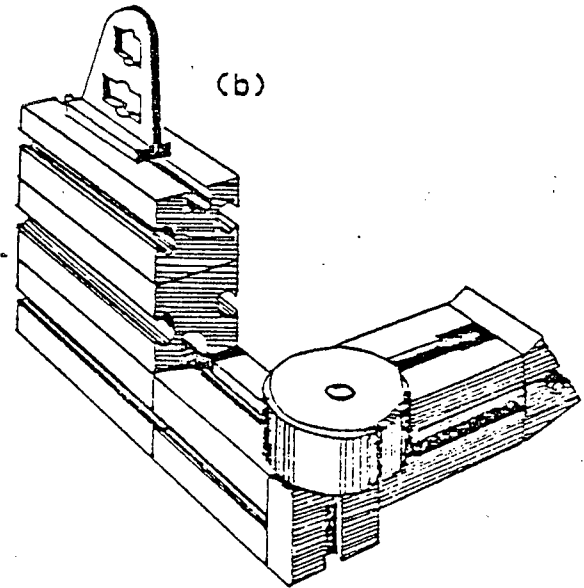
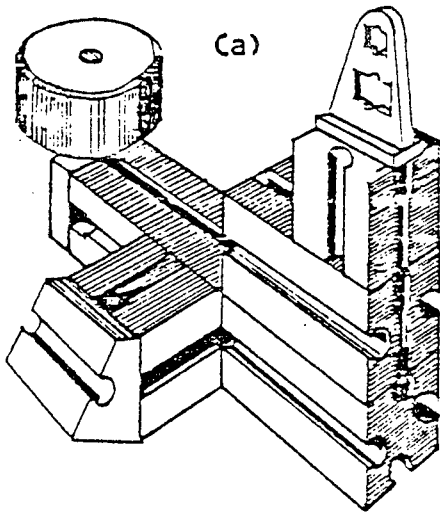
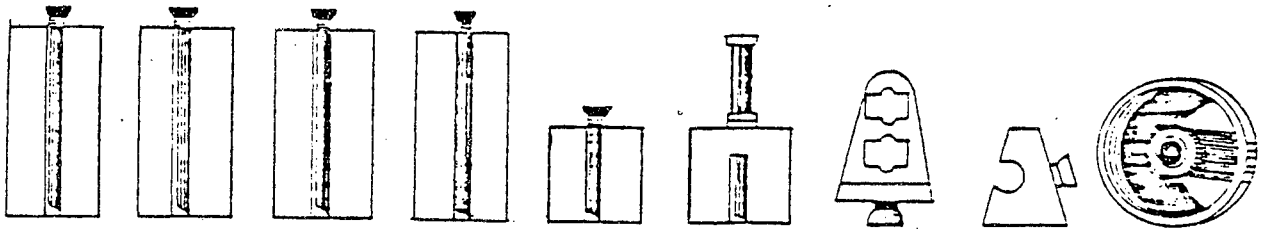
The side of the large square cuts two sides of the small square into one-third parts and two-thirds parts.

What is the area where the squares overlap?



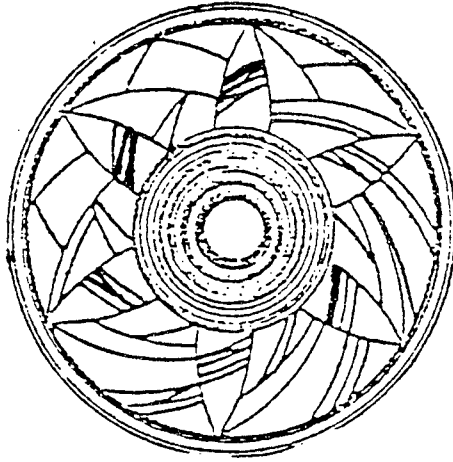
- (a) one-third square metre
- (b) one-fifth square metre
- (c) one-quarter square metre
- (d) two-thirds square metre
- (e) two-fifths square metre

3 . Which model will the following components fit?

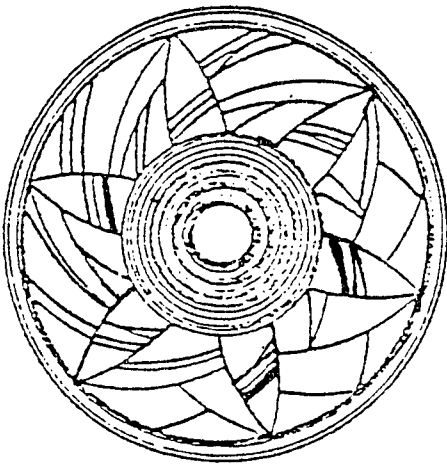


- 4 Among the five drawings,
four are identical. The fifth drawing is
different. Which one is it?

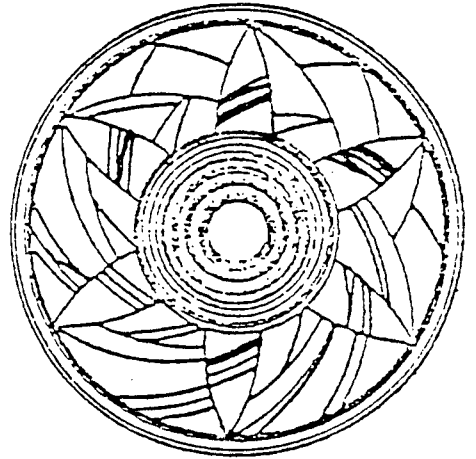
(a)



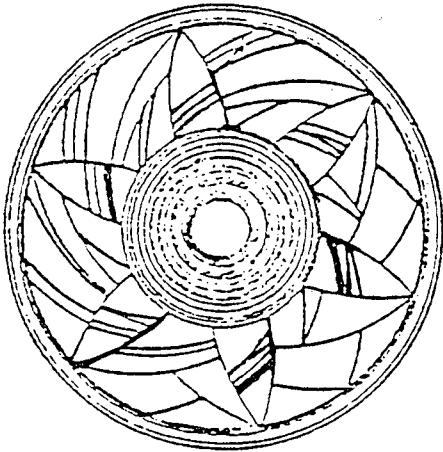
(e)



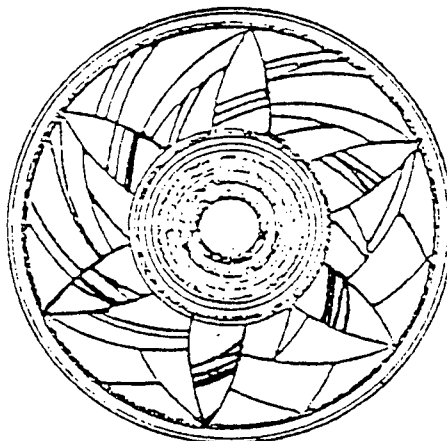
(b)



(d)



(c)



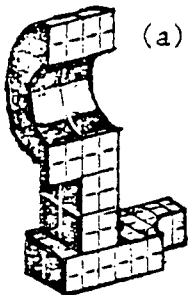
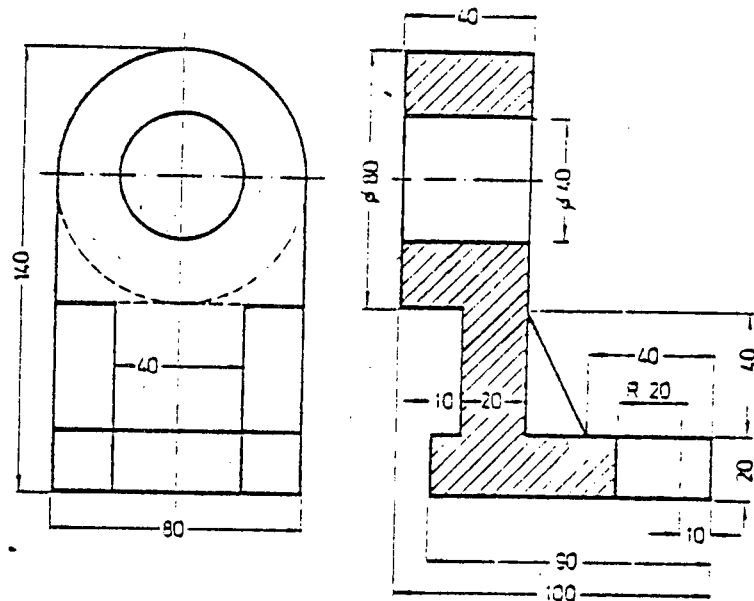
- 5 An air squadron has about fifty planes. Its flight pattern is an equilateral triangle; every plane except the first is halfway between two planes ahead of it. Several planes are shot down in combat. When the squadron returns, the planes form four equilateral triangles. The lost planes could have formed another equilateral triangle.

If all these triangles are different in size, how many planes were there to begin with?

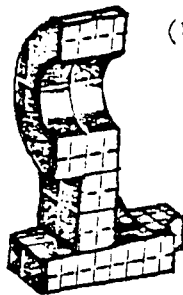


- (a) 52
- (b) 49
- (c) 45
- (d) 66
- (e) 55

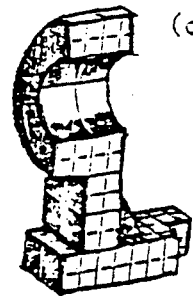
- 6 If only the left-hand half of the model is to be built from the drawing below, choose the correct model from the five alternatives.



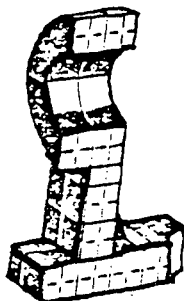
(a)



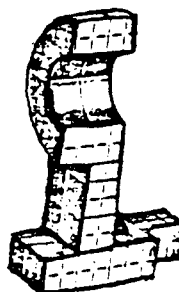
(b)



(c)



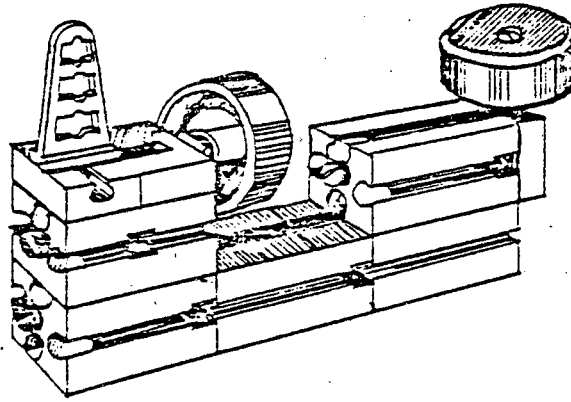
(d)



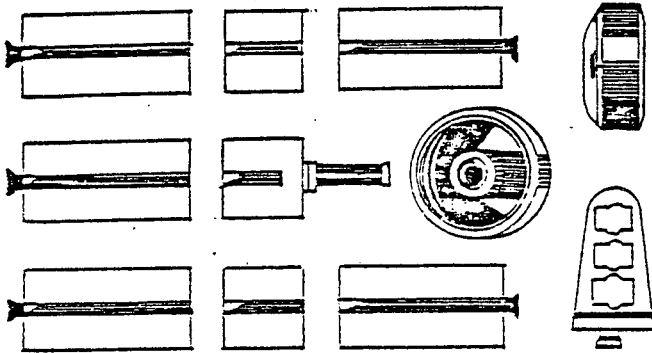
(e)

7

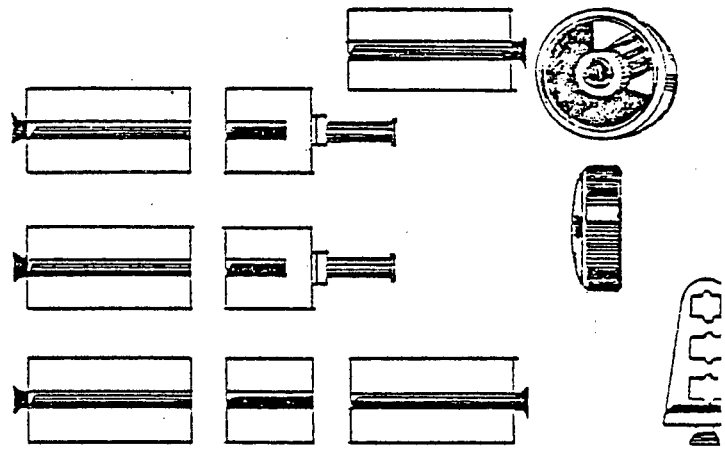
Which set of components will give the following model?



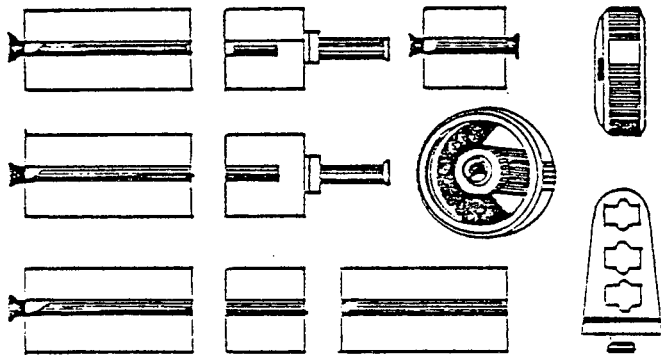
(a)



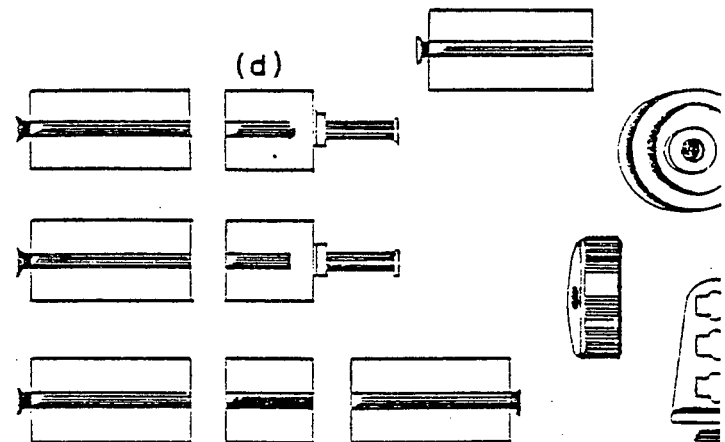
(b)



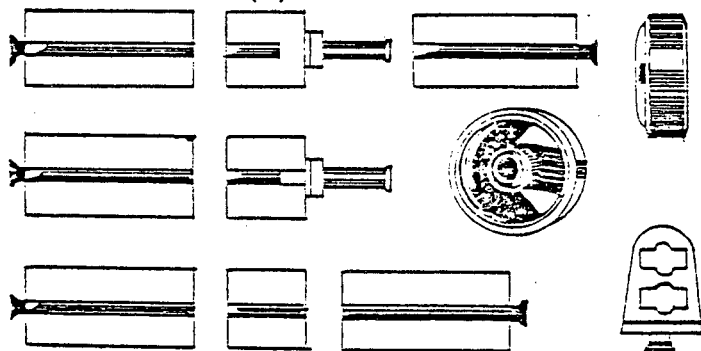
(c)



(d)

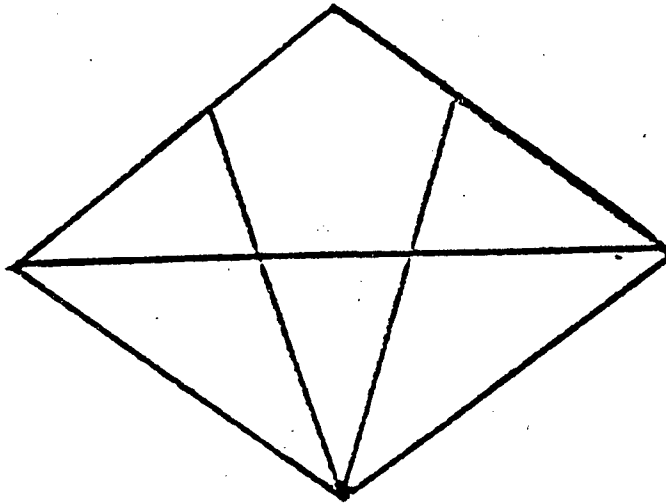


(e)



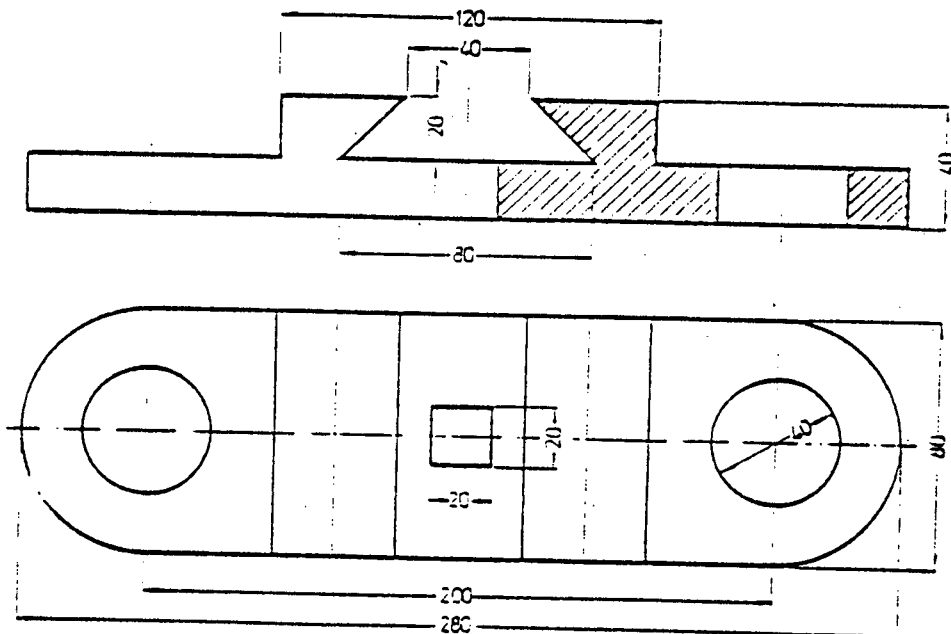
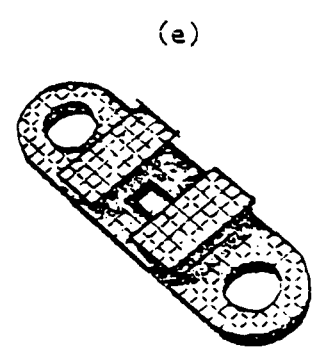
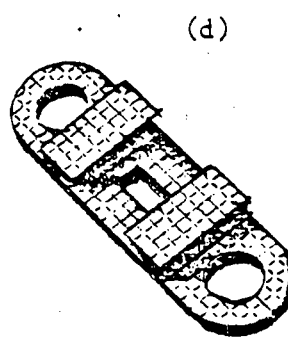
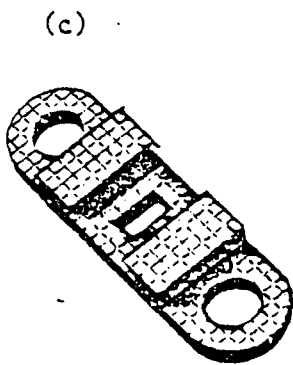
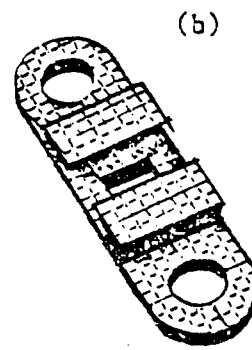
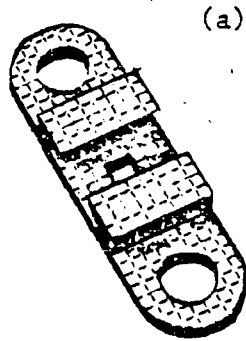
8

How many triangles are there in the diagram?
Can you count them methodically enough not to miss any?

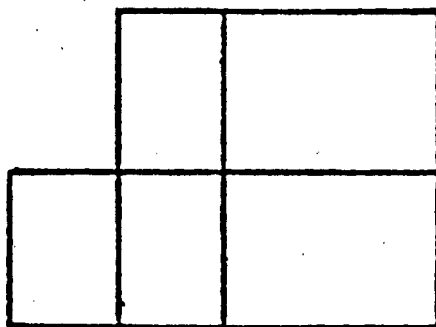


- (a) 11
- (b) 12
- (c) 9
- (d) 7
- (e) 10

- 9 If a quarter section is removed from the model, which model represents the drawing below?



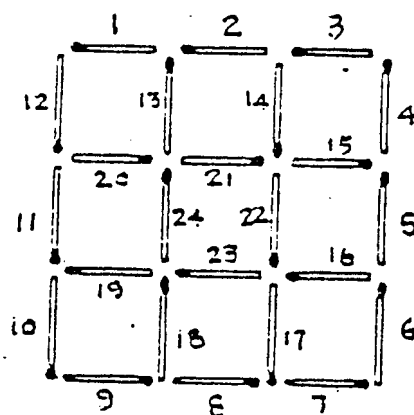
- 10 How many rectangles are there in the diagram? (Note: A square is a rectangle)



- (a) 13
- (b) 10
- (c) 11
- (d) 9
- (e) 12

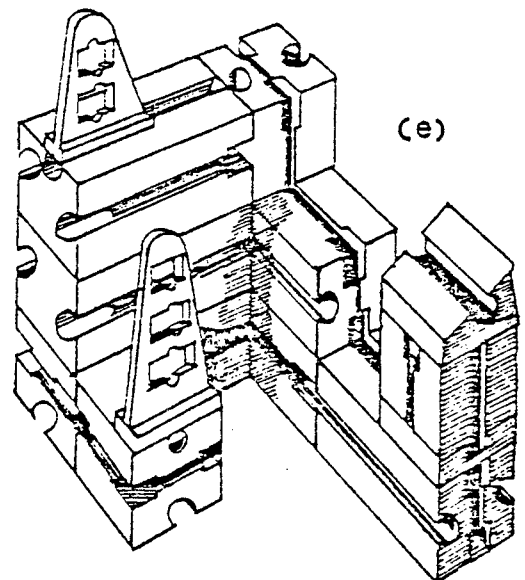
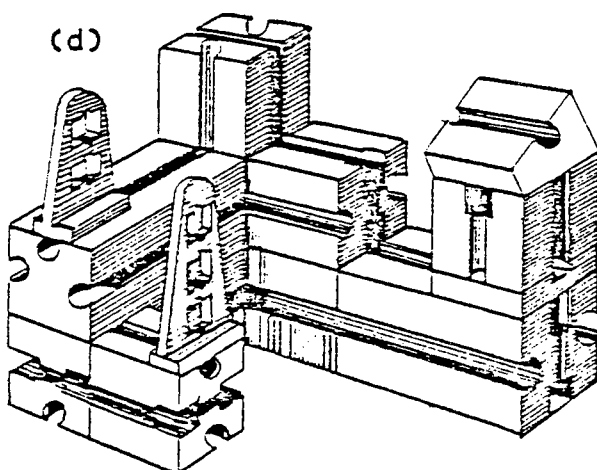
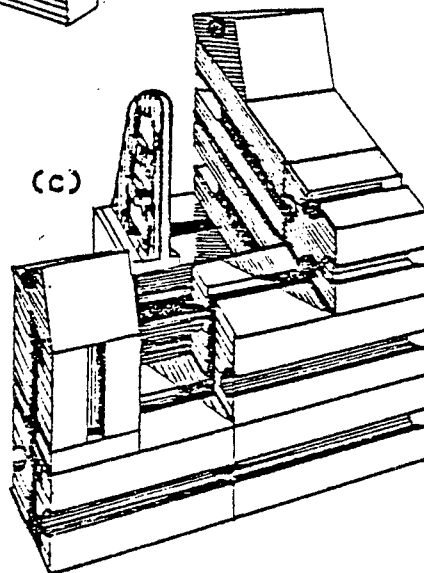
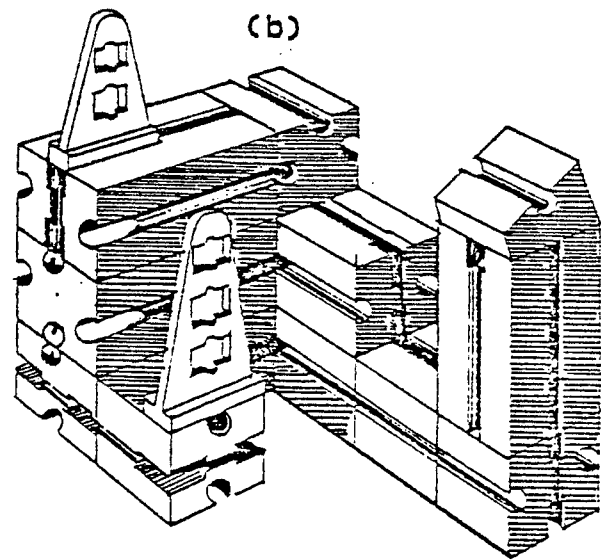
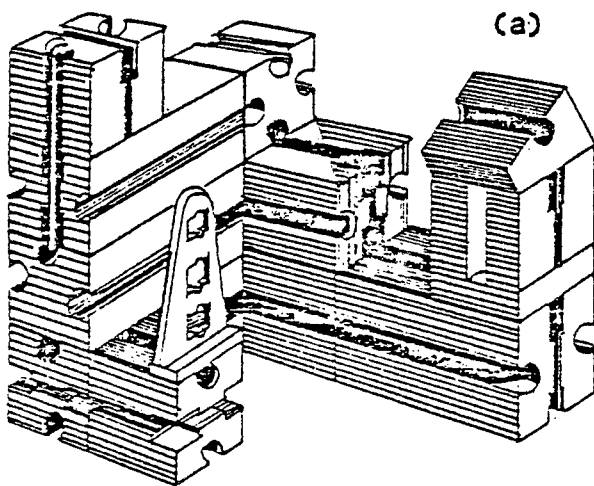
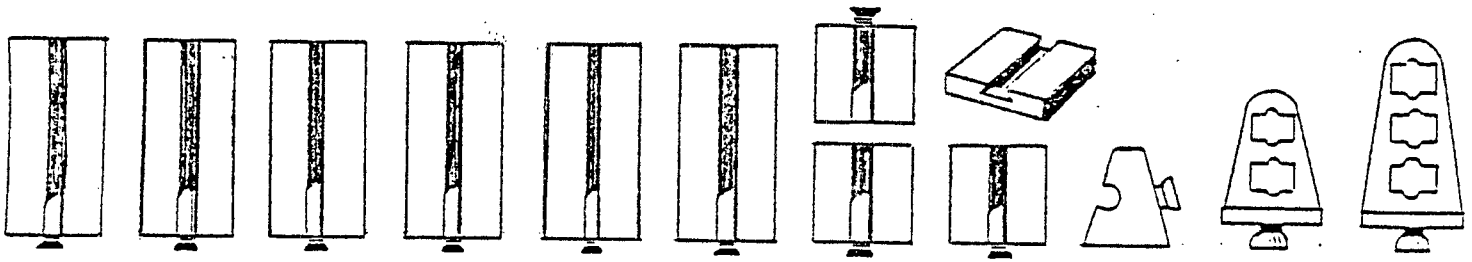
- 11 Which six matches should you remove, without changing the position of the others, so that only three squares are left?

NB: All the remaining squares must be of different sizes.



- (a) 13; 14; 16; 17; 18; 19
- (b) 14; 15; 16; 17; 18; 19
- (c) 13; 14; 19; 20; 22; 23
- (d) 15; 16; 17; 18; 19; 20
- (e) 13; 14; 19; 20; 21; 24

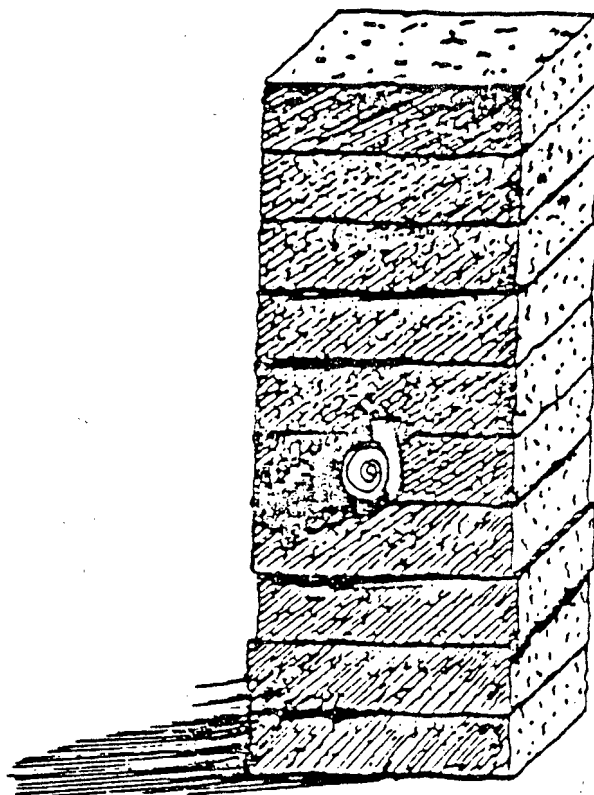
12 Which model will the following components fit?



13

A snail has undertaken to climb a pile of ten bricks. It can climb four bricks in an hour. But then, since the effort has been extremely tiring, it must sleep for an hour, during which it slips down three bricks.

How long will the snail take to reach the top of the pile?



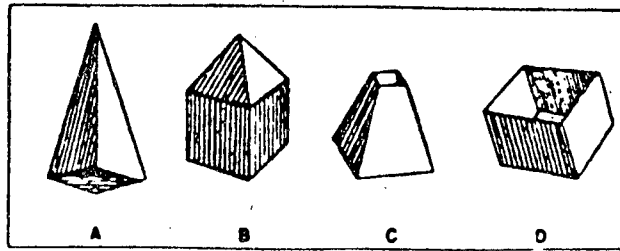
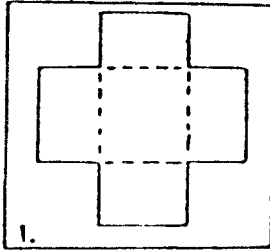
- (a) 10 hours
- (b) 12 hours
- (c) 20 hours
- (d) 15 hours
- (e) 13 hours

STOP

WAIT FOR FURTHER INSTRUCTIONS

INSTRUCTIONS

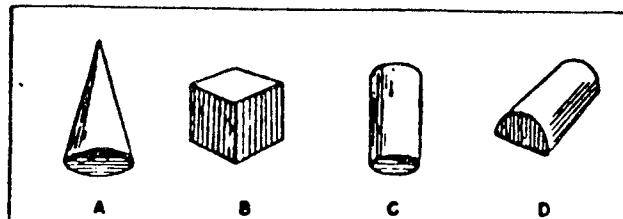
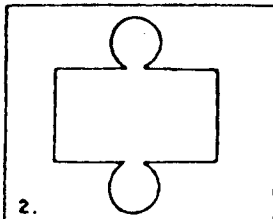
On this page are some exercises in finding objects made from pieces of metal or cardboard. Look at exercise 1 below.



D

At the left is a drawing which represents a flat piece of metal. The dotted lines show where the metal is to be bent. At the right are drawings of four objects. Notice that only object D can be made by bending the metal piece in figure 1. Therefore, D is the correct answer.

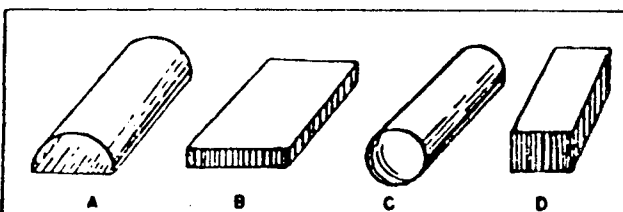
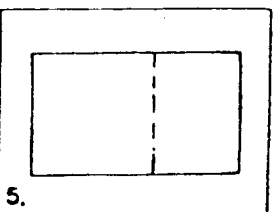
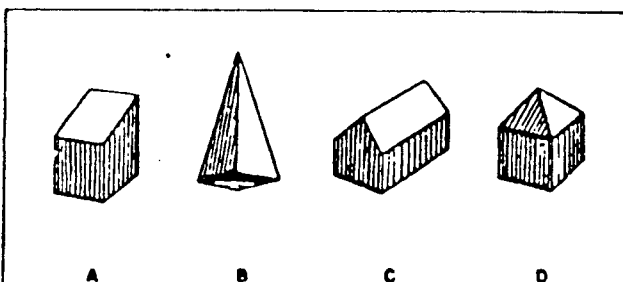
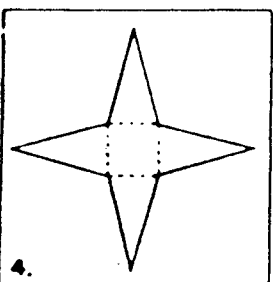
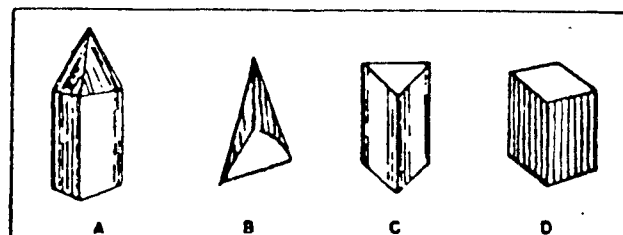
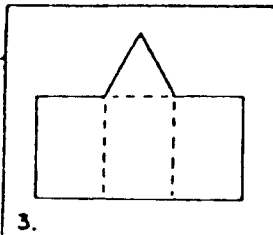
Look at exercise 2.



C

At the left is another drawing of a flat piece of metal. Only object C can be made from figure 2, this time by both rolling and bending the metal. C has been chosen as the answer.

Look at them but do not mark this page. Here are some more exercises for practice.



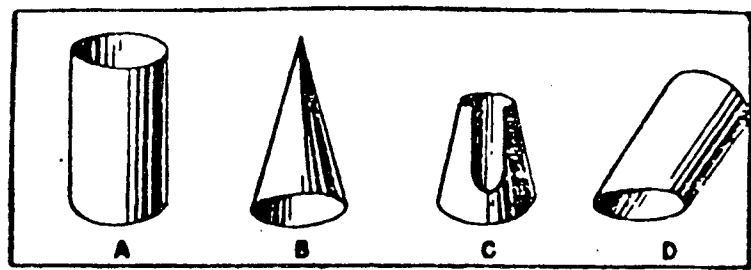
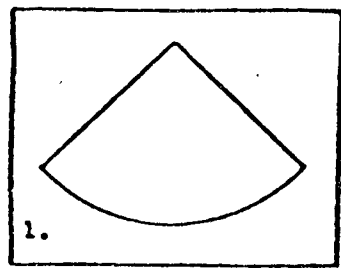
Do not turn this page until you are told to do so.

On the following pages are more exercises like these. In each exercise only one object can be made from the flat piece of metal by either bending, or rolling or both. Choose its letter on the ANSWER SHEET.

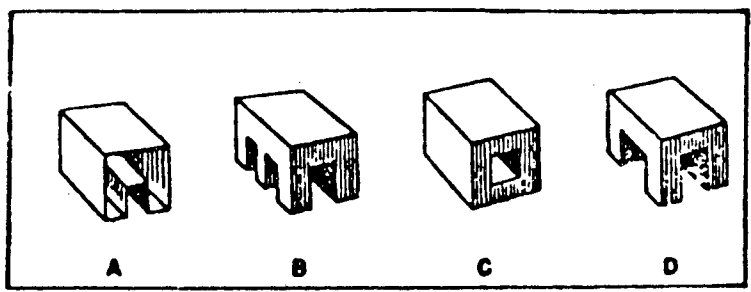
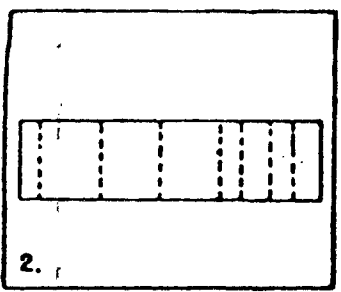
Work as fast and accurately as you can.

You will be allowed 5 minutes.

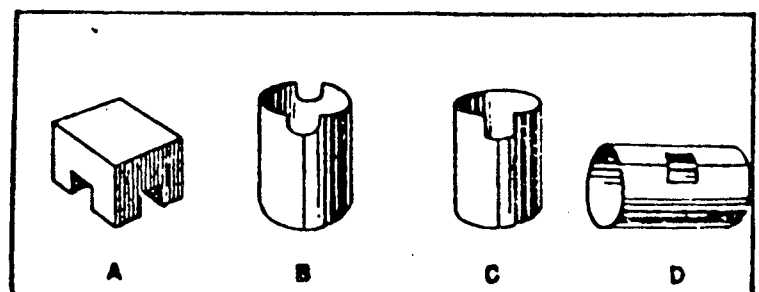
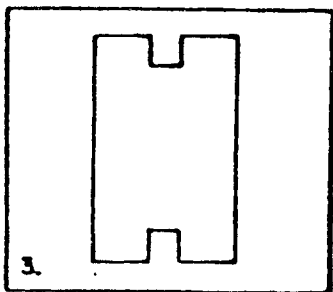
SECTION THREE



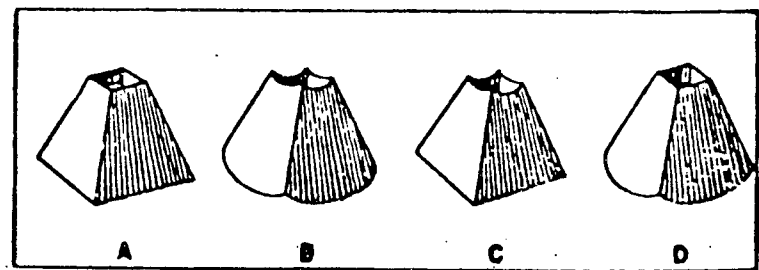
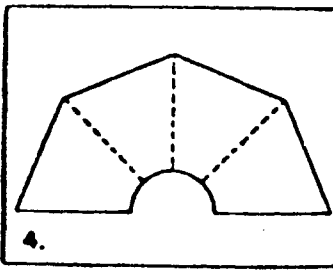
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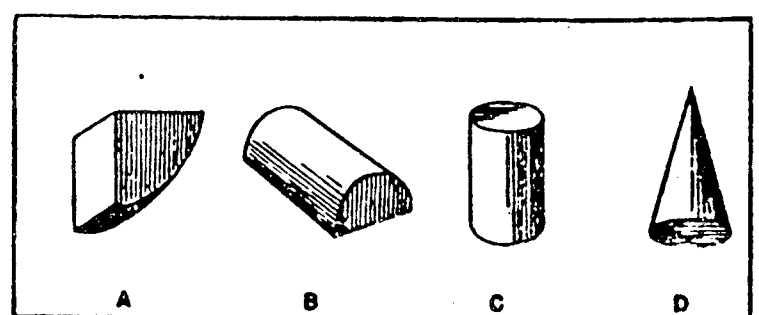
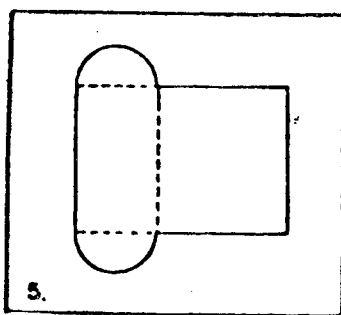
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3

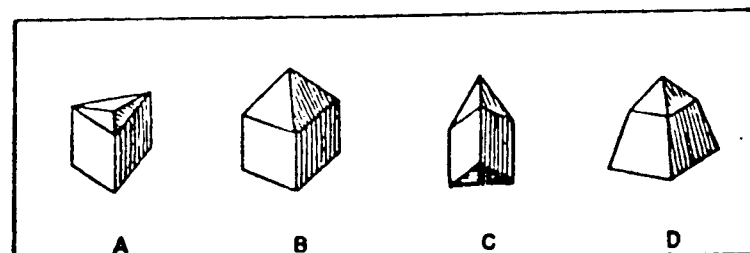
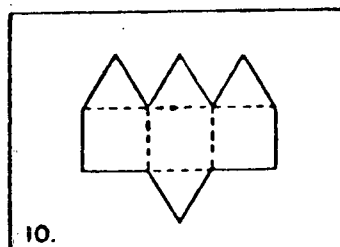
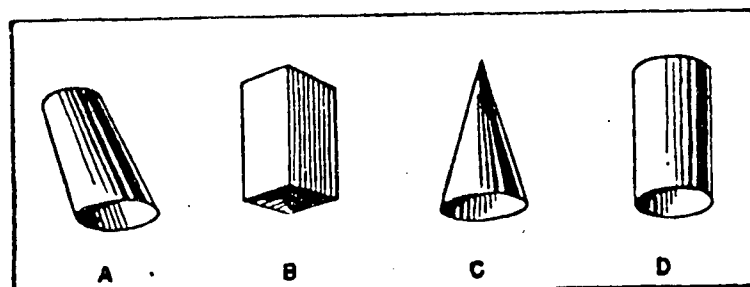
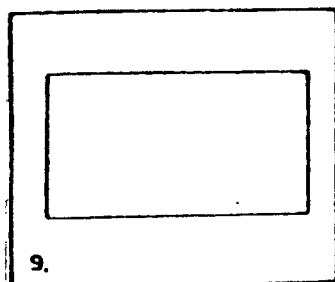
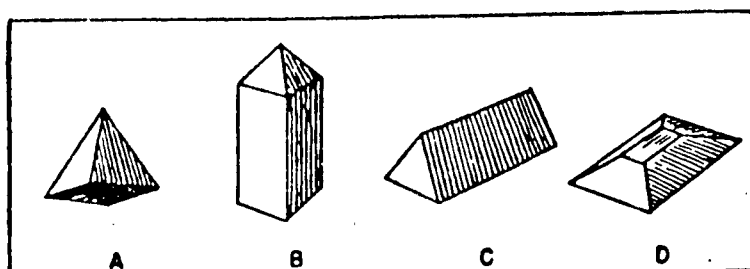
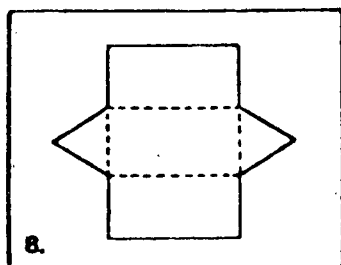
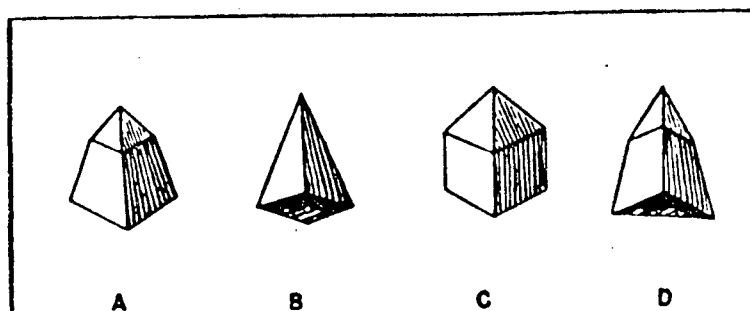
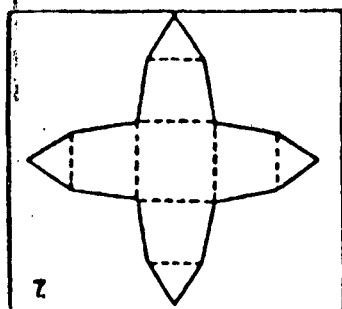
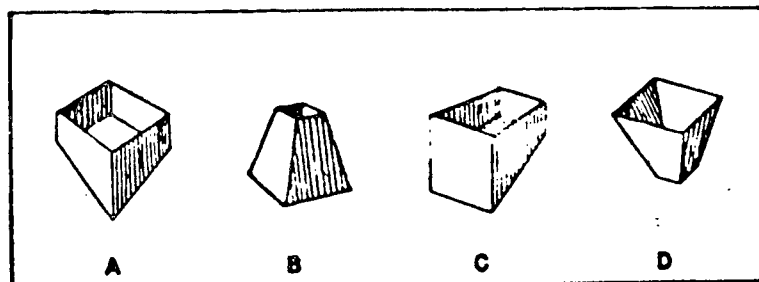
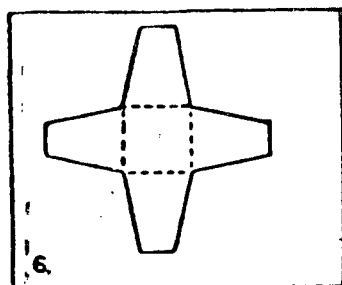


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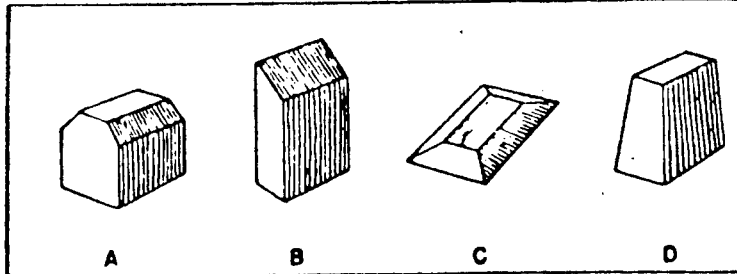
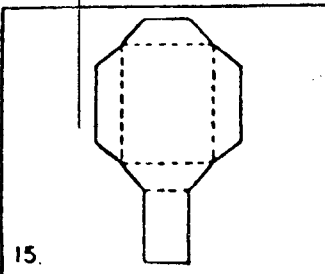
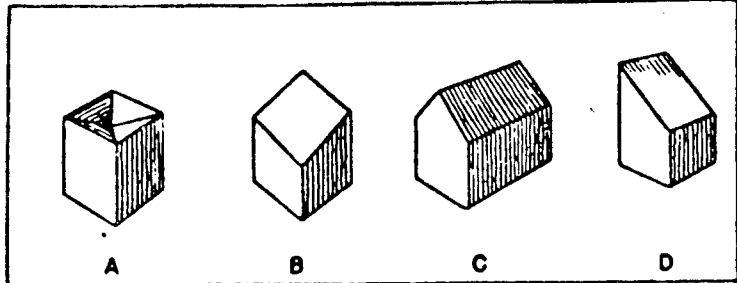
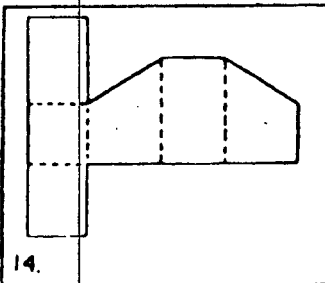
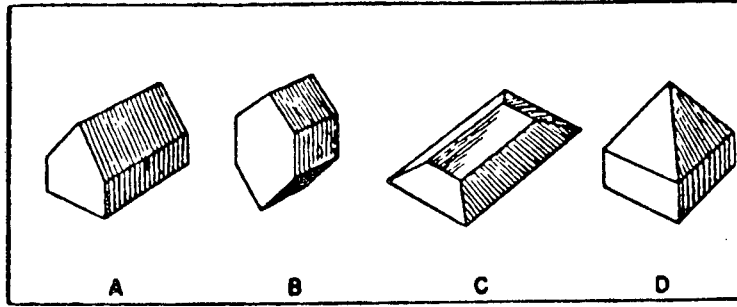
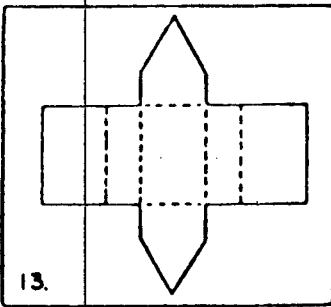
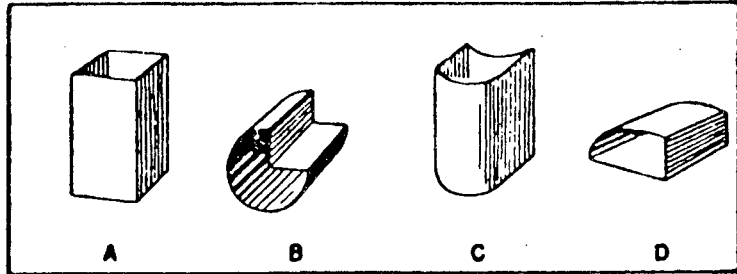
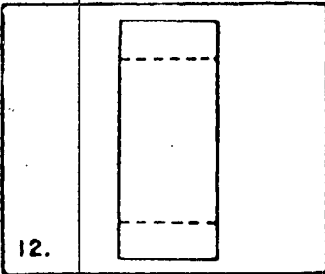
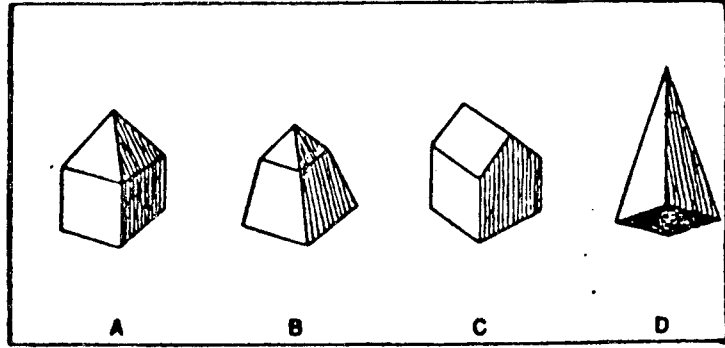
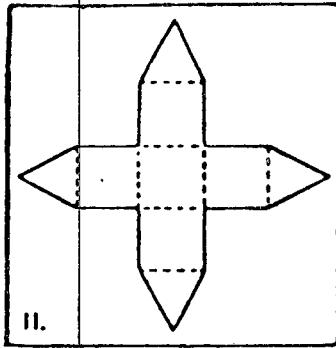


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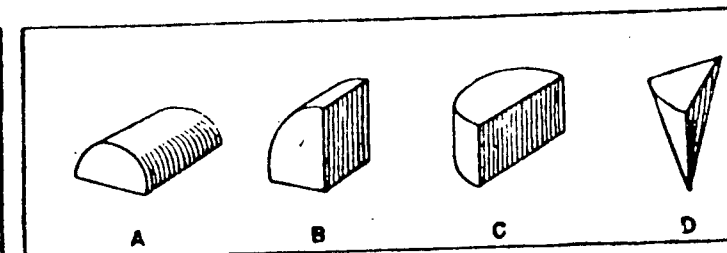
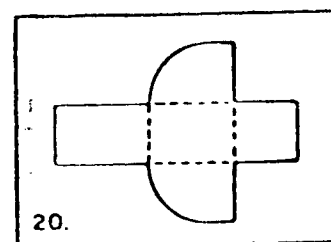
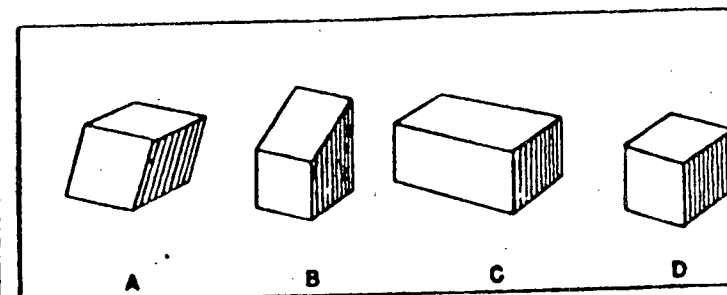
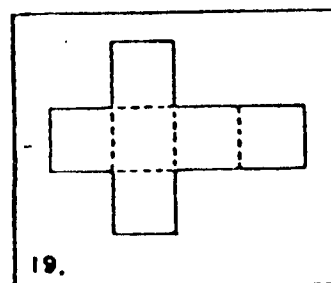
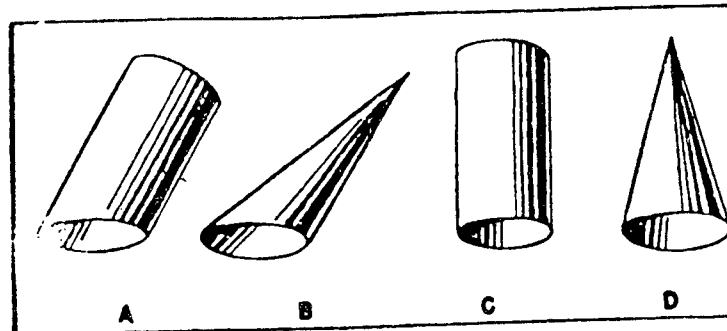
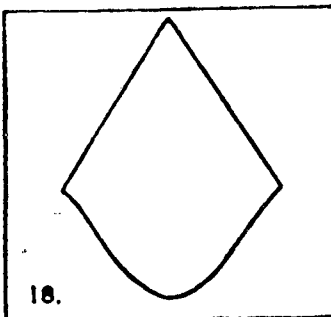
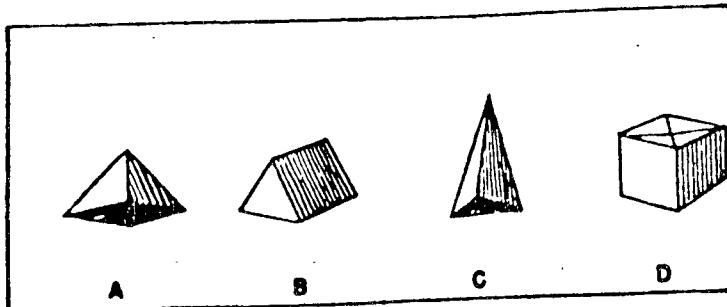
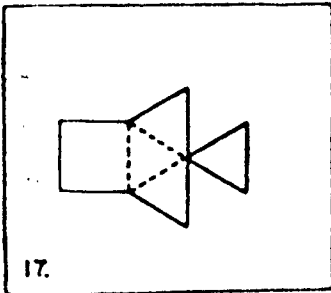
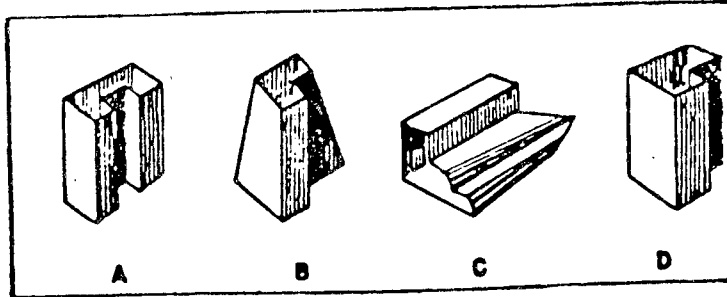
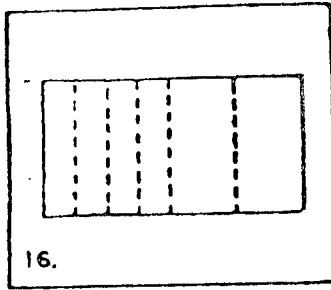
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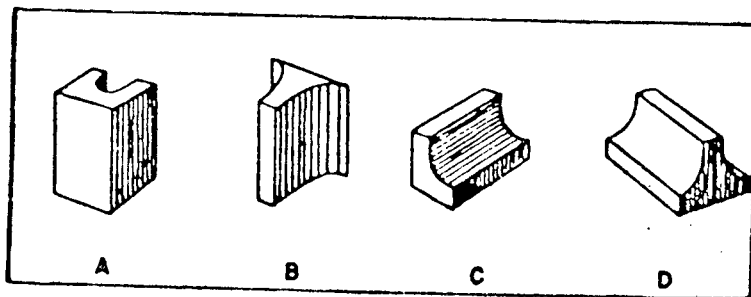
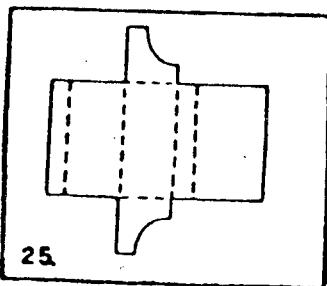
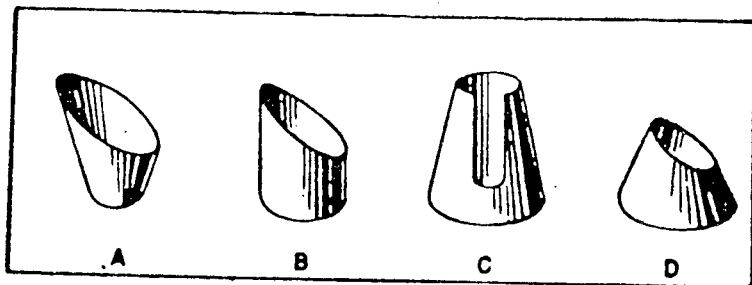
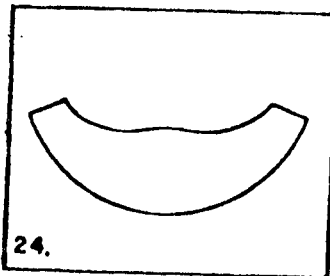
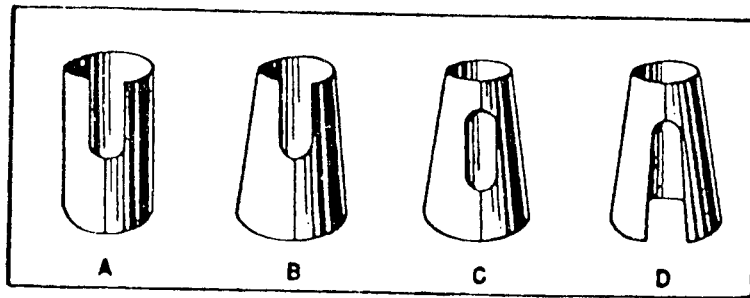
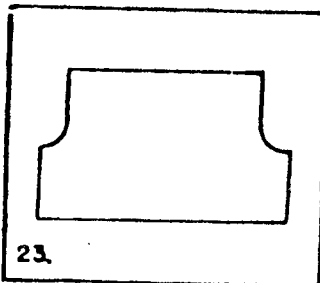
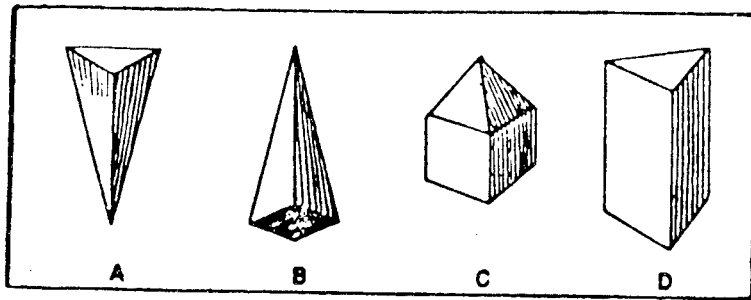
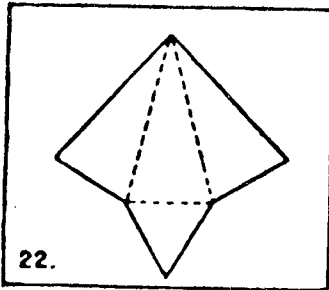
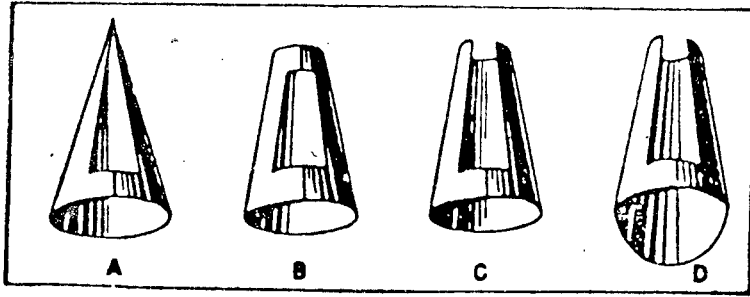
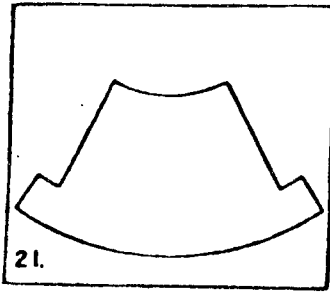


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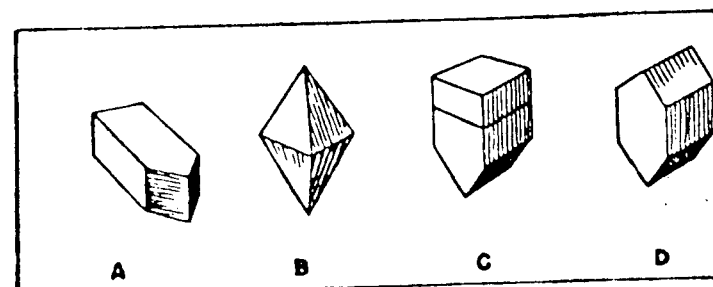
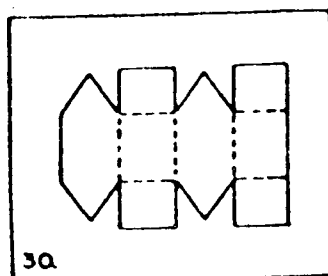
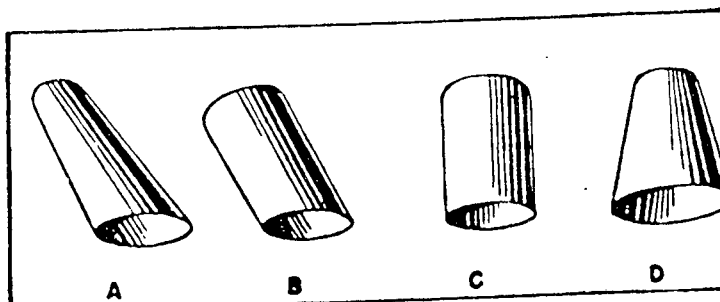
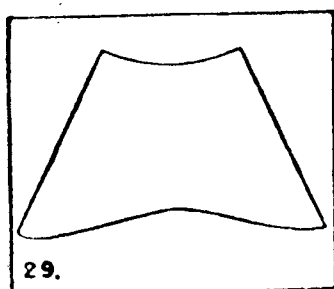
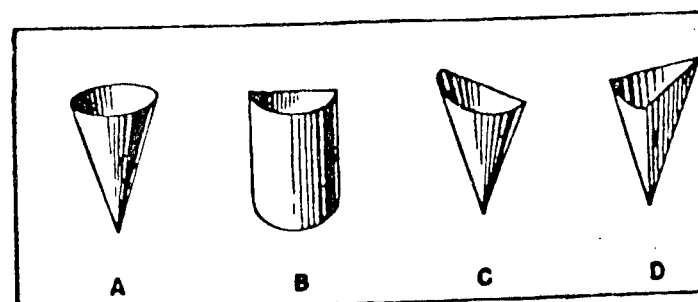
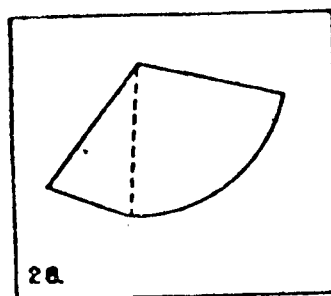
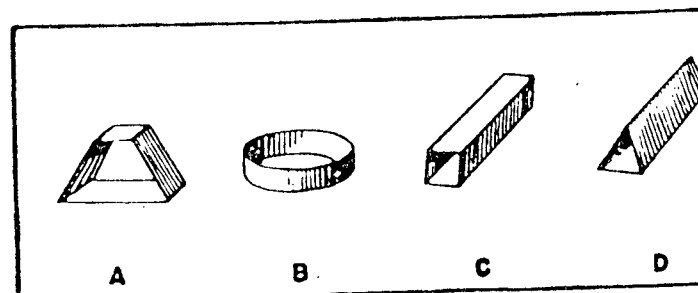
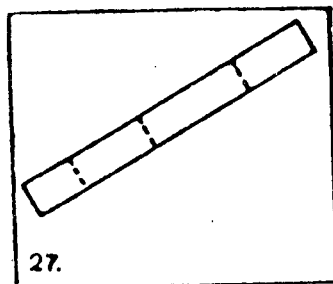
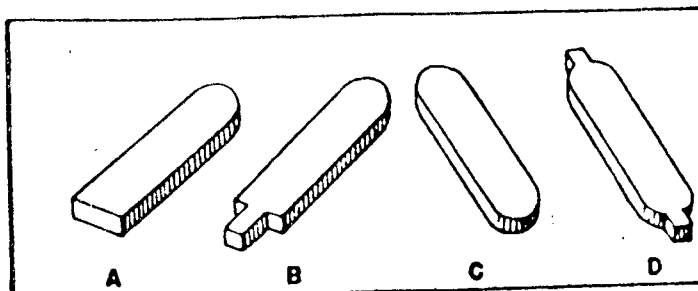
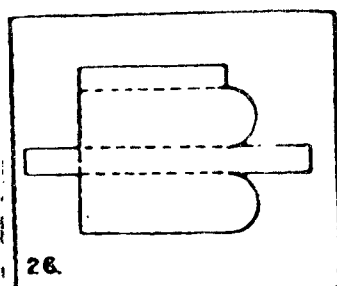


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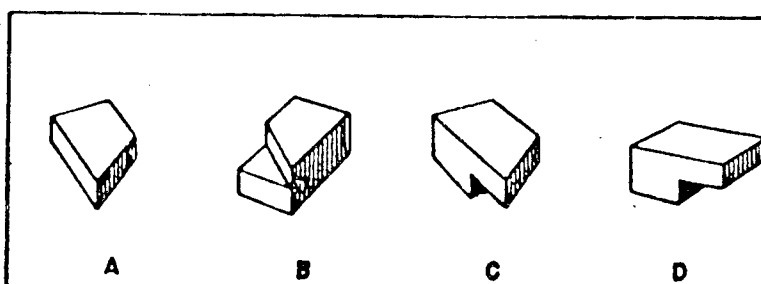
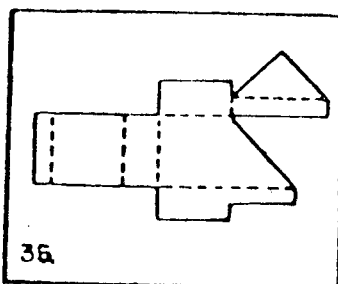
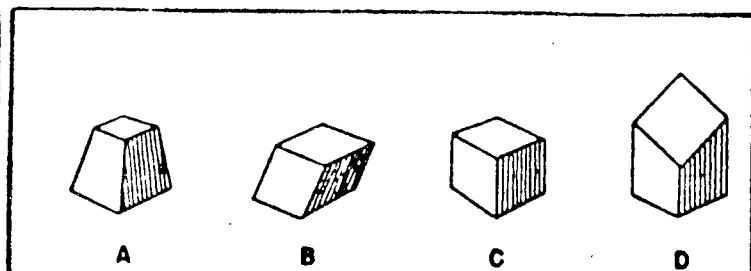
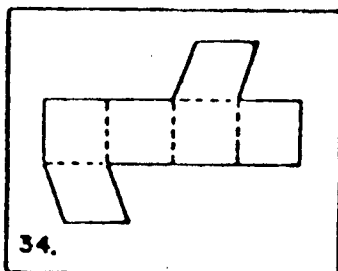
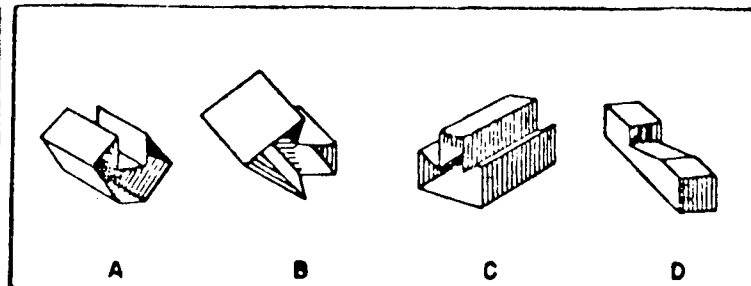
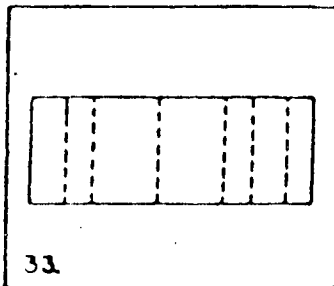
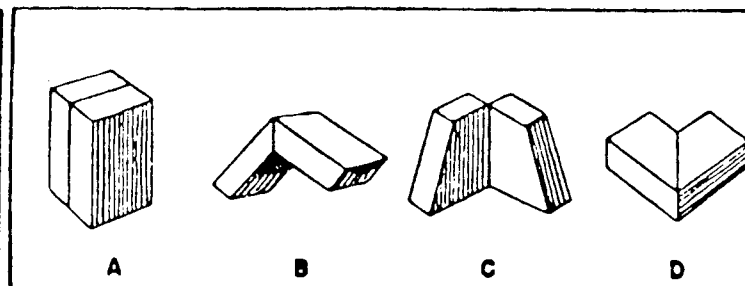
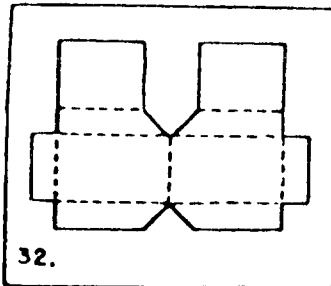
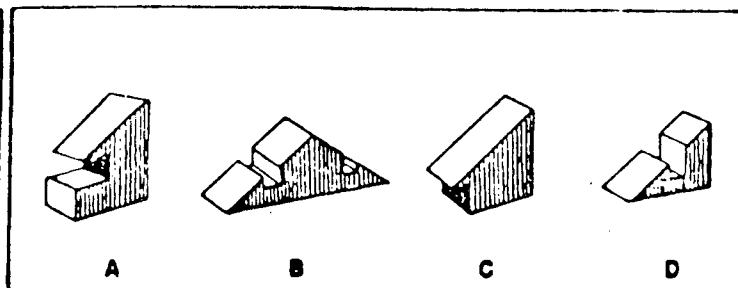
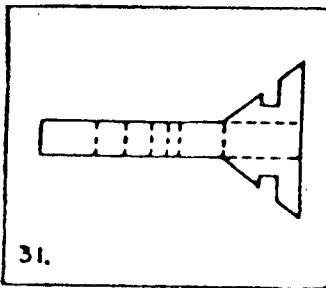




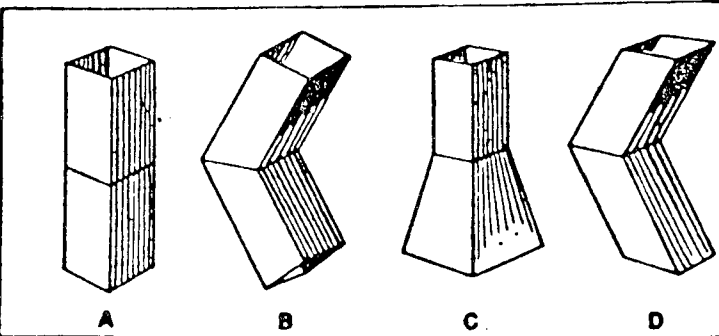
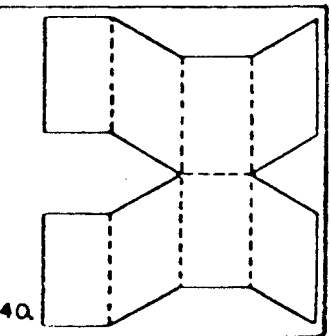
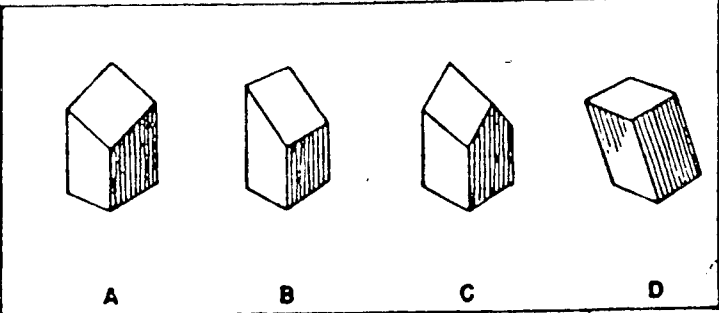
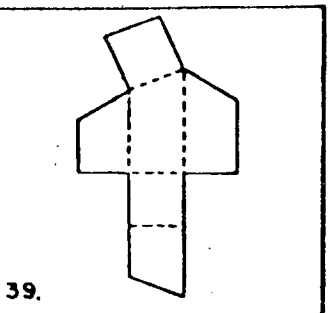
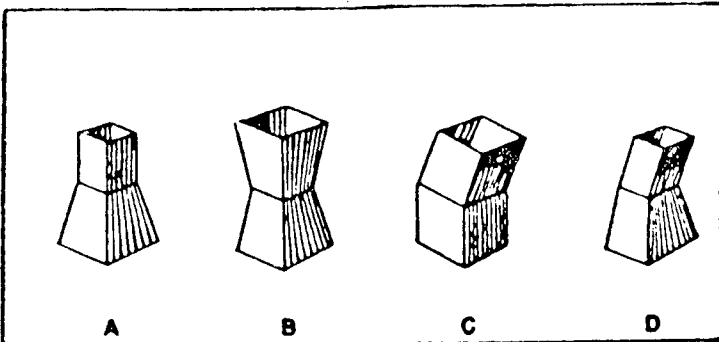
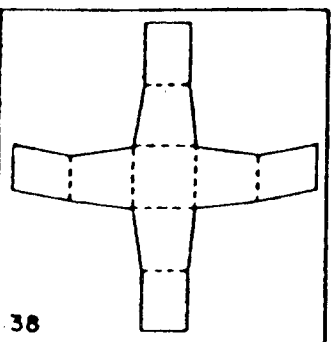
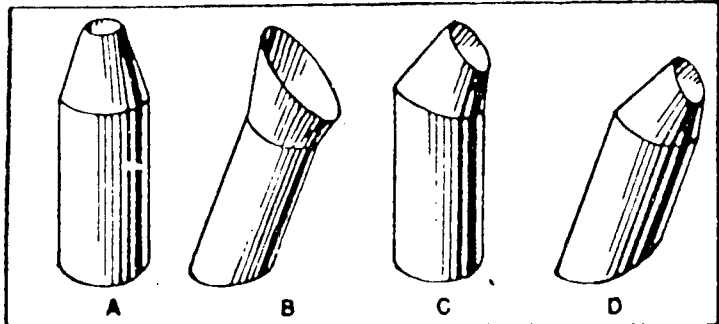
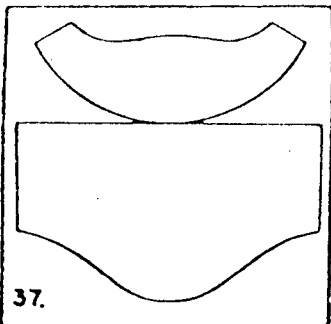
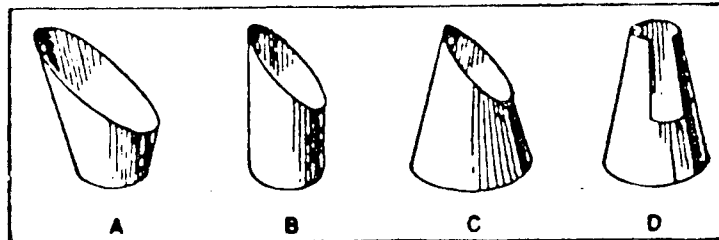
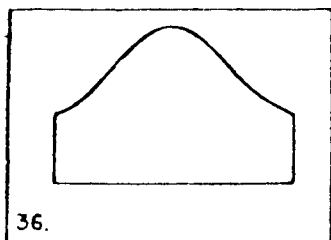
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STOP

WAIT FOR FURTHER INSTRUCTIONS

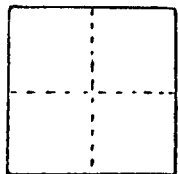
YOU HAVE FIVE MINUTES IN TOTAL FOR SECTION FOUR A,B,C

SECTION FOUR - PART A

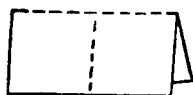
PRACTICE TEST PAPER FOLDING

Here is a square

A



It is folded in half.



And then in half again.

B



The dotted lines show the folds.

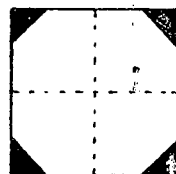
Suppose you cut away a piece from the folded square B, it might look like this:

The shaded part is the cutaway part.



What would it look like if you unfolded the whole square again?

Like this:

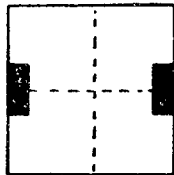
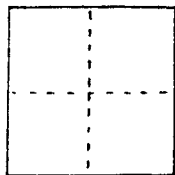


Now look at this one.

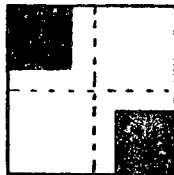
When the folded square B has a piece cut off one side as shown by the shading, and it is then unfolded again, it will look like . . . number 3.

A

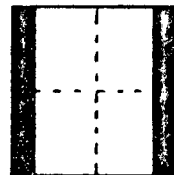
B



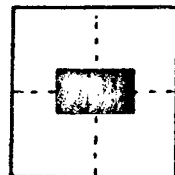
1



2



3

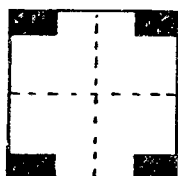
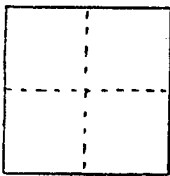


4

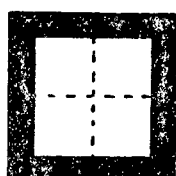
Now try this one.

A

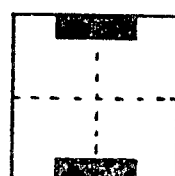
B



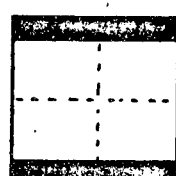
1



2



3



4

SECTION FOUR - PART A

PAPER FOLDING

What will the paper look like when it is unfolded after being cut as indicated? Put a cross in the correct block on your ANSWER SHEET.

			(a)	(b)	(c)	(d)
1.						
2.						
3.						
4.						
5.						
6.						
7.						
8.						
9.						
10.						

Go Straight On To The Next Page

SECTION FOUR - PART A

PAPER FOLDING

43

Continue as on last page. However, this time the paper is folded diagonally. Put a cross in the correct block on your ANSWER SHEET.

			(a)	(b)	(c)	(d)
11.						
12.						
13.						
14.						
15.						
16.						
17.						
18.						
19.						
20.						

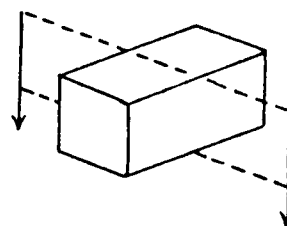
Go Straight On To The Next Page

SECTION FOUR — PART B

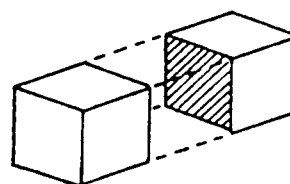
PRACTICE TEST

BLOCK CROSS-SECTIONS

This diagram represents a wooden block which is to be sawn vertically into two parts in the place shown by the dotted lines.

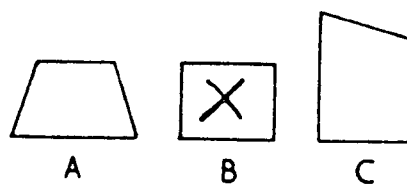


In this next diagram the two halves are moved apart to show the cut face. This cut face is shaded.



The cut face is the same shape as one of these three drawings.

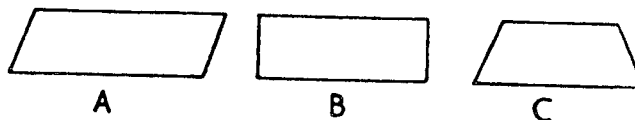
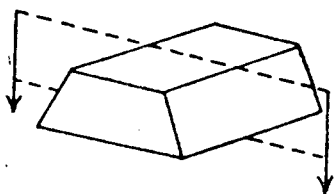
B is the correct shape and so is marked with a cross (X).



TRIAL QUESTION

What would be the shape of the cut face if the block shown below is cut where shown?

DO NOT write on this page.



Go Straight On To The Next Page

Each question shows a block of wood. Imagine a cut made where shown by the dotted lines. What would be the shapes of the cut faces if the blocks below were cut where shown? Put a cross in the correct block on your ANSWER SHEET.

	BLOCKS	SHAPES		
1.		A	B	C
2.		A	B	C
3.		A	B	C
4.		A	B	C
5.		A	B	C
6.		A	B	C
7.		A	B	C
8.		A	B	C
9.		A	B	C
10.		A	B	C

Carry Straight On To The Next Page

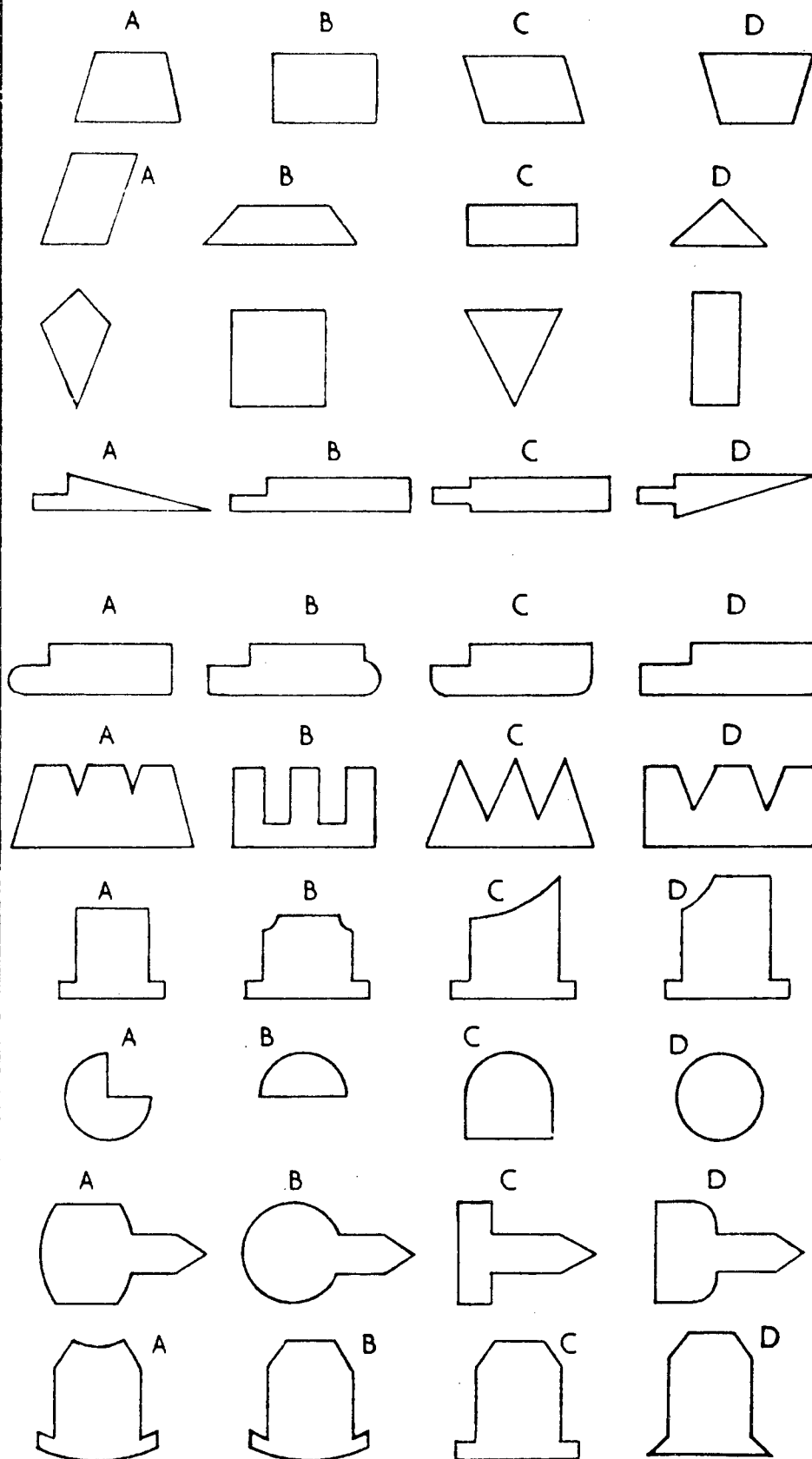
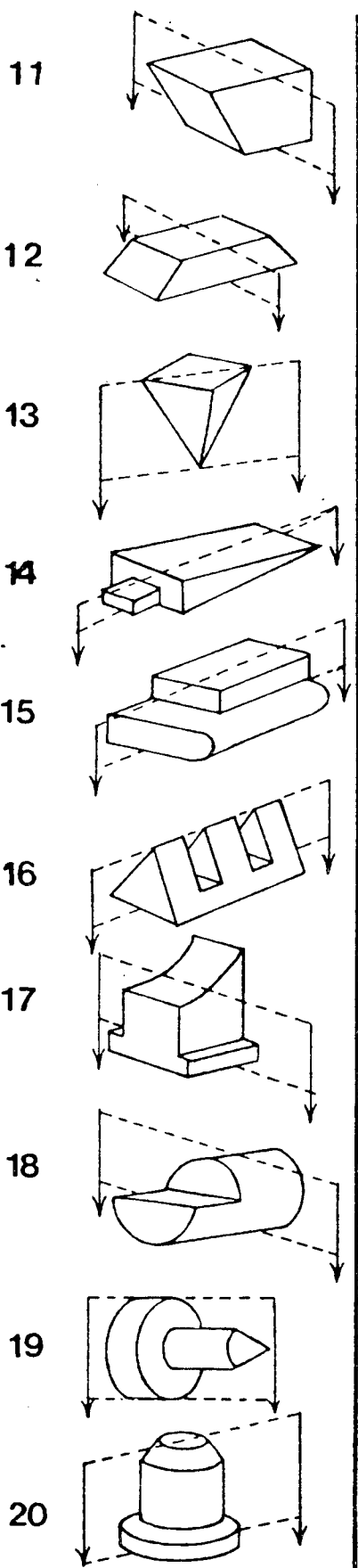
BLOCK CROSS-SECTIONS

Continue As On The Last Page

This time there are four shapes to choose from.

BLOCKS

SHAPES

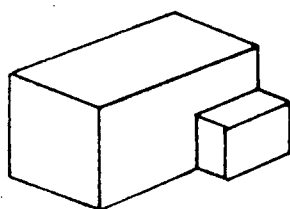


Carry Straight On To The Next Page

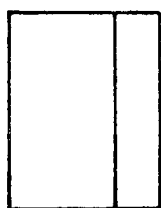
TOP VIEWS

PRACTICE TEST

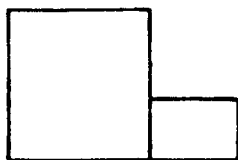
Below is a model made of blocks placed together and next to it are four drawings. One of these drawings shows the view of the model looking down on it from above.



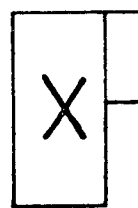
MODEL



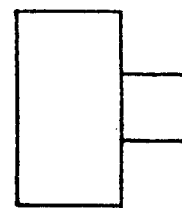
A



B



C

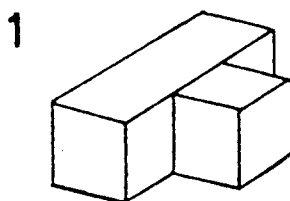


D

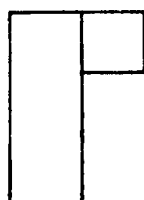
A cross (X) has been placed on diagram C because it shows the view looking down on the model from above.

TRIAL QUESTIONS

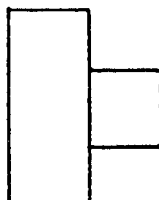
Place a cross (X) on the diagram (A, B, C or D) which you think shows the model if you were looking down on it from above.



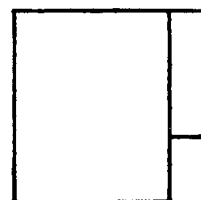
MODEL



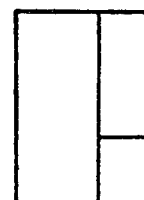
A



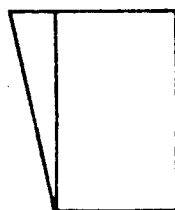
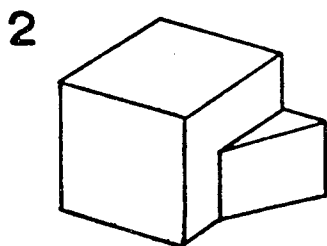
B



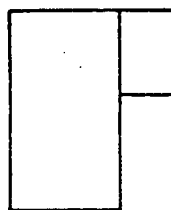
C



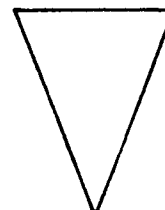
D



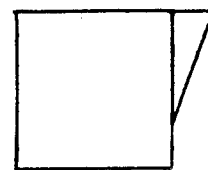
A



B



C



D

TOP VIEWS

On each line the left-hand drawing shows several blocks placed together. Choose one of the four drawings on the right of the thick black line which shows the view looking down on the blocks. Put a cross in the correct block on your ANSWER SHEET.

1		A 	B 	C 	D
2		A 	B 	C 	D
3		A 	B 	C 	D
4		A 	B 	C 	D
5		A 	B 	C 	D
6		A 	B 	C 	D
7		A 	B 	C 	D
8		A 	B 	C 	D
9		A 	B 	C 	D
10		A 	B 	C 	D

ME EXAM
32/84

UNIVERSITY OF CAPE TOWN

DEPARTMENT OF MECHANICAL ENGINEERING

UNIVERSITY EXAMINATION

ENGINEERING DRAWING : NOVEMBER 1984

B.Sc. in Mechanical Engineering

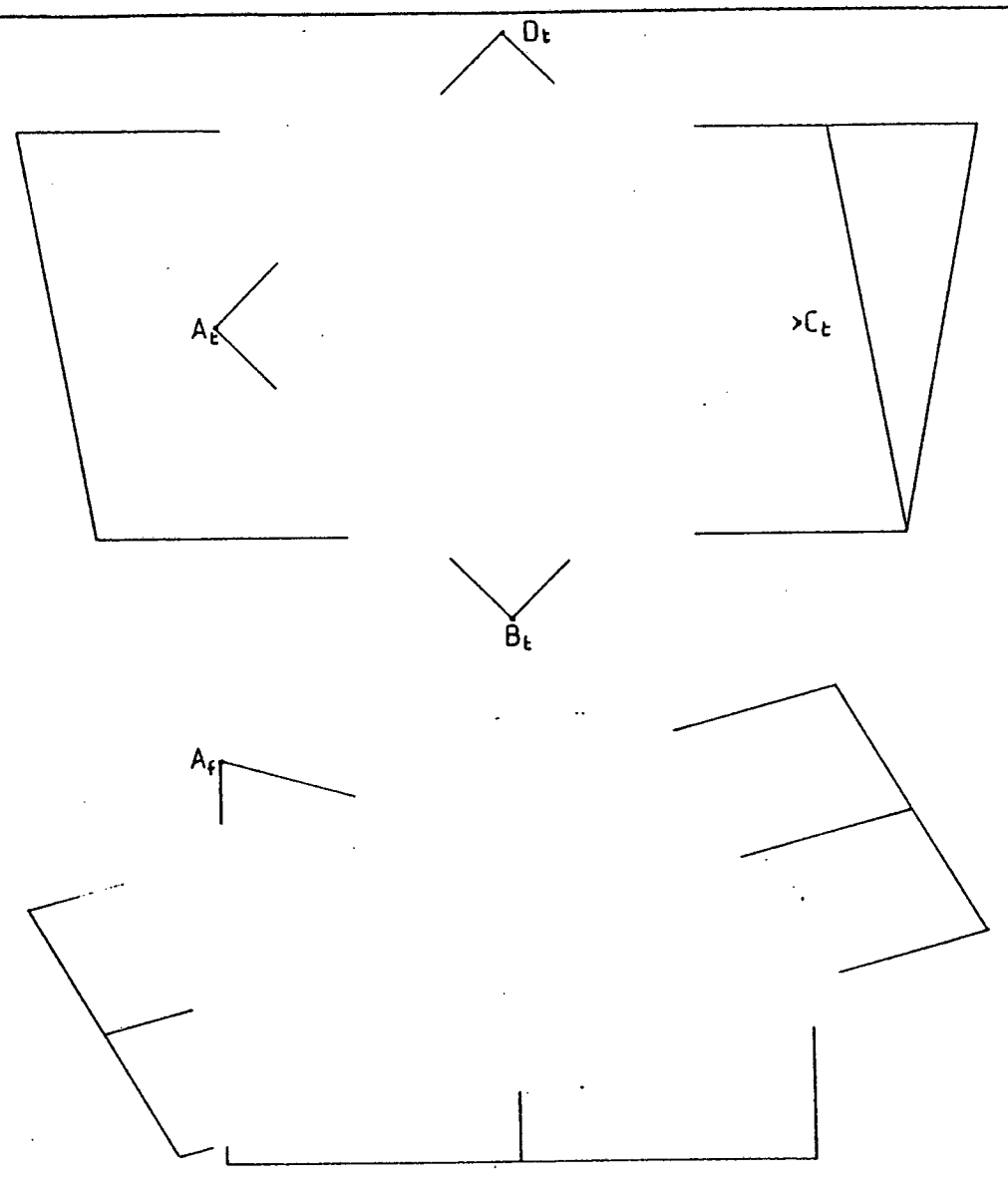
Time : FOUR Hours

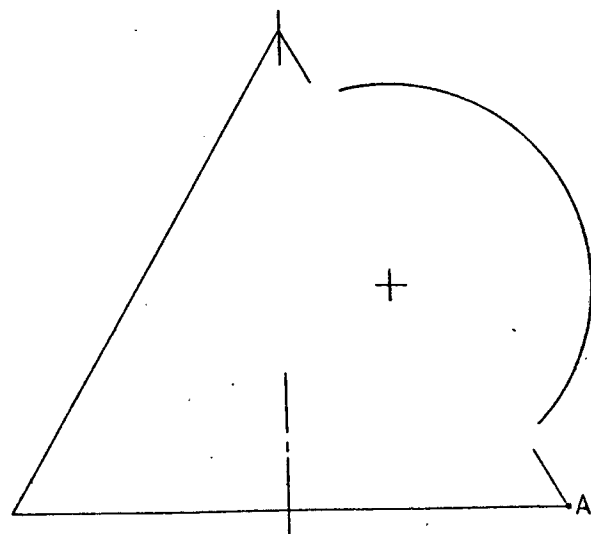
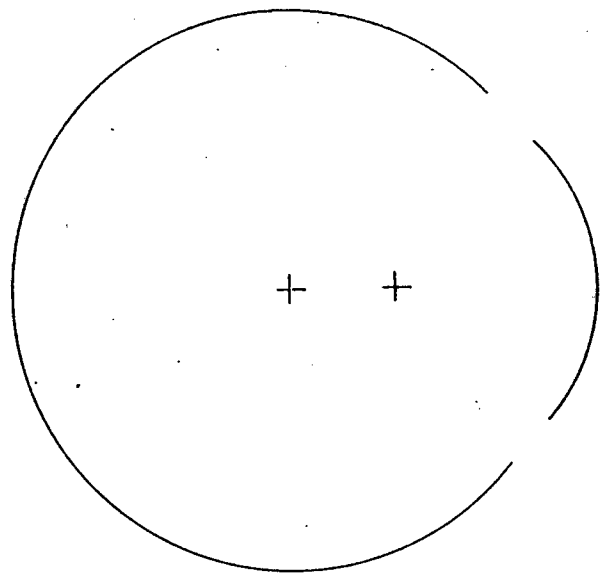
Internal examiner : Mr. A. Sass

External examiner : Mr. A.H. Hofmeyr

Note:

1. Write your name on ALL SIX worksheets.
2. Complete FIVE worksheets.
3. All worksheets are of the same value.
4. Credit will only be given for solutions where the construction or method is clearly shown. Presentation is therefore important.
5. All orthographic projections are in third angle.
6. All Worksheets, whether attempted or not, must be handed in at the end of the examination period.
7. Remove any masking tape or staples from the worksheets and see that the sheets are arranged in the order as presented.
8. New sheets will only be available in exchange for spoilt sheets.

<div></div>		<p>Given: The incomplete front and top views of a hollow object formed by the intersection of a triangular prism and a square prism. The points A, B, C, and D are all in the same plane. B and D are the same distance from the horizontal reference plane.</p> <p>Required: Complete the two views and project a right side view of the object. Show all hidden detail except in the side view.</p>						
WORK SHEET	Question ONE	SCALE 1:1	ESTIMATED TIME	ACTUAL TIME	INITIALS	SURNAME	DESK NO	MARKS
		DATE	Minutes	Minutes				
EXERCISES IN ENGINEERING GRAPHICS AND DESIGN								



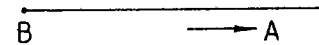
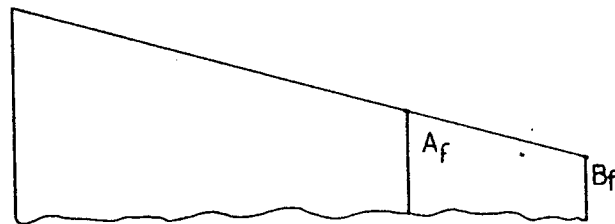
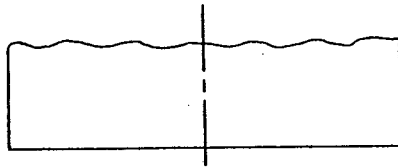
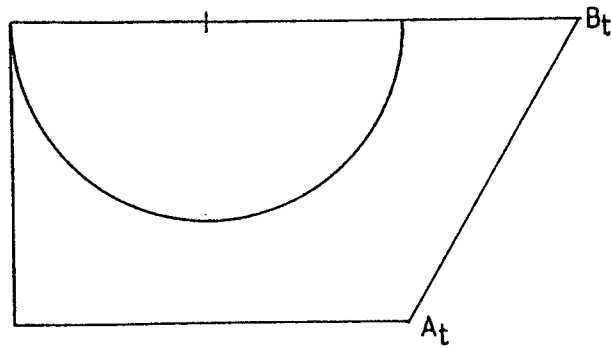
Given: The incomplete front and top views of a hollow object formed by the intersection of a right circular cone and sphere.

Required: Complete the two views showing all hidden detail. Then, in the space provided, draw a full development of the cone. The development must be symmetrically spaced about the point A.

+

A

WORK SHEET	Question TWO	SCALE 1 : 1	ESTIMATED TIME	ACTUAL TIME	INITIALS	SURNAME	DESK NO	MARKS
		DATE						
EXERCISES IN ENGINEERING GRAPHICS AND DESIGN			Minutes	Minutes				



Given: The position and shapes of the ends of two ducts. One of the ducts is semicircular the other has the shape of a trapezium.

Required: Design a transition piece to join the two ducts and then develop the transition piece in the space provided. Any construction must be clearly labelled and fold lines must be clearly drawn.

WORK SHEET

Question THREE

SCALE 1 : 1

DATE

ESTIMATED
TIME

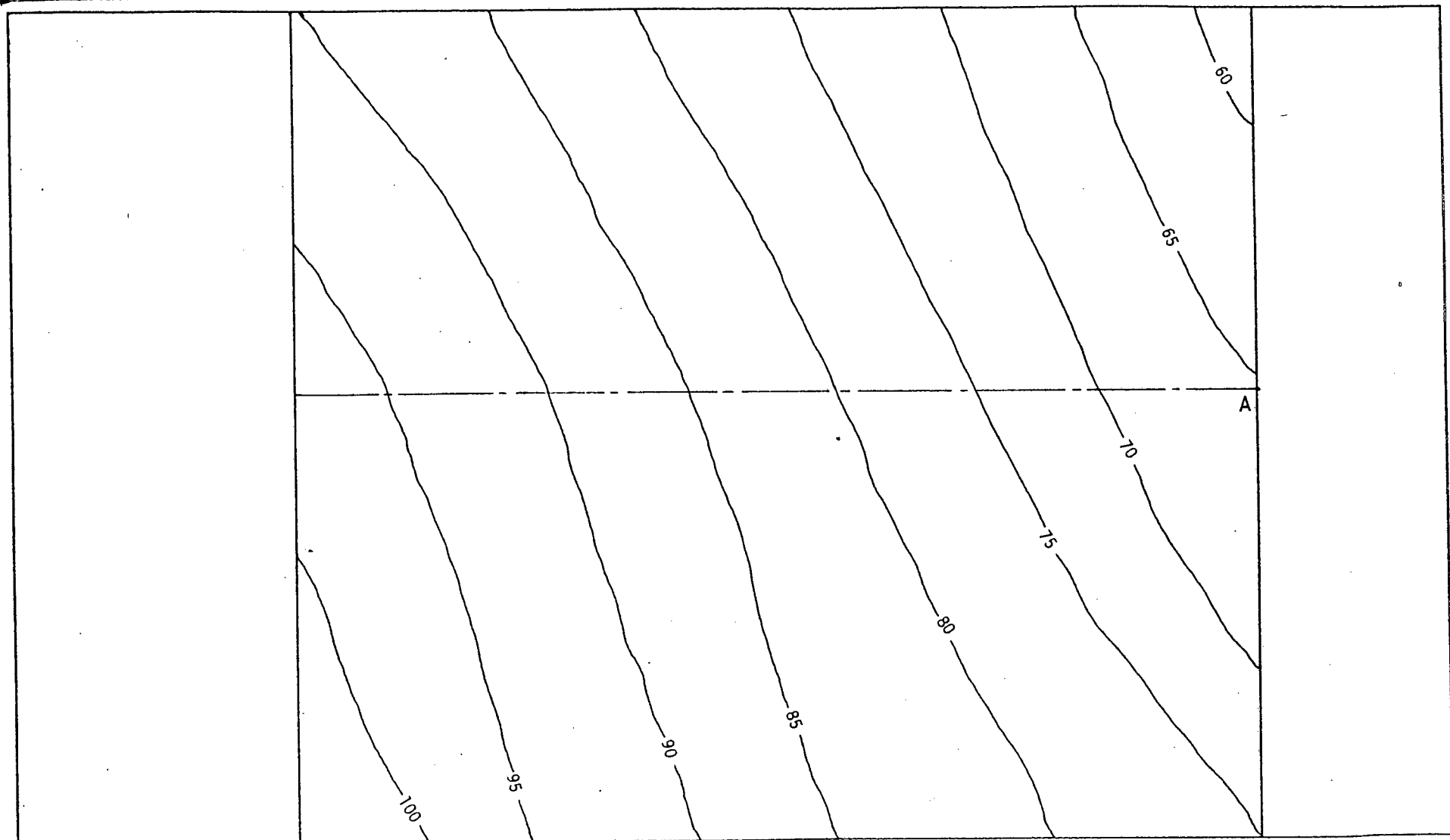
ACTUAL
TIME

INITIALS

SURNAME

DESK NO

MARKS



Given: The centre line of a proposed road is shown on the contour map above. The road is to be 20 metres wide with an elevation of 90 metres at A. From A the road is to have a downward slope of 1 in 6. Cuttings and embankments are to have a slope of 45 degrees.

Required: Show the limits of the cuttings and embankments required to build the road and draw the contours on these cuttings and embankments. In the spaces provided, draw vertical profiles through the 60 and 90 metre contours on the road.

WORK SHEET

Question FOUR

SCALE 1:1000

DATE

ESTIMATED
TIME

ACTUAL
TIME

INITIALS

SURNAME

DESK NO

MARKS

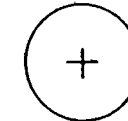
Given: Information for a plate cam with roller follower

1. Camshaft diameter 20 mm and drawn
2. Base circle diameter 40 mm
3. Roller diameter 20 mm
4. Offset of line of action 10 mm and drawn
5. Rotation of cam - anticlockwise

Motion information

1. SHM from 0 to 80 degrees, lift 0 to 40 mm
2. Dwell from 80 to 120 degrees
3. Constant acceleration and deceleration from 120 to 200 degrees, lift from 40 to 60
4. Accelerate with SHM from 200 to 260 degrees fall, 60 to 40 mm
5. Constant velocity 260 to 300 degrees fall, 40 to 20 mm
6. Decelerate with SHM 300 to 360 degrees, fall 20 to 0 mm

Required: Using the above information, draw a displacement curve for the follower and then draw the outline of the cam in the space provided.


$$360^\circ$$

WORK SHEET	Question FIVE	SCALE 1 : 1	ESTIMATED TIME	ACTUAL TIME	INITIALS	SURNAME	DESK NO	MARKS
		DATE						

APPENDIX TWO

A P P E N D I X 2

2.1 - POPULATION 1

1983 - REGRESSION EQUATIONS

JUNE 1983 (N=185)

1. Using only the UCT spatial battery score as the independent variable,

$$y = 23,633 + 0,5554x_1$$

	T Statistic	
b ₁	8,748 *	UCT Spatial battery

- * Significant at 1% level

$$r^2 = 0,54$$

2. Using UCT spatial battery score, Spargo science score, Matriculation mathematics, Matriculation aggregate as independent variables,

$$y = 7,87 + 0,53x_1 - 0,17x_2 + 0,31x_4$$

	T Statistics	
b ₁	8,08 *	UCT spatial battery
b ₂	-0,59	Spargo science test
b ₃	-0,25	Matriculation mathematics
b ₄	2,75 *	Matriculation aggregate

- * Significant at 1% level. Negative coefficients for x₂ and x₃ imply multicollinearity problems.

$$r^2 = 0,57$$

A P P E N D I X 2

2.2 - POPULATION 1

1983 - REGRESSION EQUATIONS

NOVEMBER 1983 (N = 185)

1. Using only the UCT spatial battery score as the independent variable,

$$y = 30,89 + 0,45x_1$$

<u>T - Statistic</u>		
b ₁	8,12	* UCT Spatial battery

* Significant at 1% level

$$r^2 = 0,52$$

2. Using UCT spatial battery score, Spargo science test, Matriculation mathematics, Matriculation aggregate as independent variables,

$$y = 8,88 + 0,41x_1 + 0,4x_4$$

<u>T - Statistic</u>		
b ₁	7,27	* UCT spatial battery
b ₂	-0,02	Spargo science test
b ₃	-0,42	Matriculation mathematics
b ₄	4,0	* Matriculation aggregate

* Significant at 1% level. Negative coefficients for x₂ and x₃ imply multicollinearity problems.

$$r^2 = 0,58$$

A P P E N D I X 2

2.3 - POPULATION 2

1984 - REGRESSION EQUATIONS

JUNE 1984 (N = 232)

1. Using only the Glasgow spatial battery score as the independent variable,

$$y = - 2,6 + 1,4x_1$$

	T - Statistic	
b ₁	12,6 *	Glasgow spatial battery

* Significant at 1% level.

$$r^2 = 0,66$$

2. Using Glasgow spatial score, Spargo science test, Matriculation mathematics, Matriculation aggregate as independent variables,

$$y = -1,78 + 1,34x_1 + 0,38x_2 - 0,05x_3 - 0,66x_4$$

	T Statistic	
b ₁	11,45 *	Glasgow spatial battery
b ₂	1,64	Spargo science test
b ₃	-0,05	Matriculation mathematics
b ₄	-0,56	Matriculation aggregate

* Significant at 1% level. Negative coefficients for x₃ and x₄ indicate multicollinearity problems.

$$r^2 = 0,66$$

A P P E N D I X 2

2.4 - POPULATION 2

1984 - REGRESSION EQUATIONS

NOVEMBER 1984

1. Using only the Glasgow spatial battery score as the independent variable,

$$y = 16,18 + 0,93x_1$$

	T Statistic	
b ₁	11,06	* Glasgow spatial battery

* Significant at 1% level

$$r^2 = 0,6$$

2. Using the Glasgow spatial battery score, Spargo science test, Matriculation mathematics, Matriculation aggregate as independent variables,

$$y = 9,32 + 0,89x_1 + 0,13x_2$$

	T Statistic	
b ₁	10,61	* Glasgow spatial battery
b ₂	2,02	Spargo science test
b ₃	0,001	Matriculation mathematics
b ₄	0	Matriculation aggregate

* Significant at 1% level.

$$r^2 = 0,62$$

3. Using the Glasgow spatial battery score, Matriculation mathematics, Matriculation aggregate and June ME102 as independent variables,

$$y = 4,01 + 0,36x_1 + 0,12x_2 + 0,01x_3 + 0,47x_4$$

	T Statistic	
b ₁	4,42	* Glasgow spatial battery
b ₂	2,18	Matriculation mathematics
b ₃	0,17	Matriculation aggregate
b ₄	11,77	* June ME102

* Significant at 1% level

$$r^2 = 0,79$$

A P P E N D I X 2

2.5 - POPULATION 3

1985 - REGRESSION EQUATIONS

JUNE 1985

1. Using only the Problem-solving/Spatial battery as the independent variable,

$$y = 49,24 + 0,4x_1$$

	T Statistic		
b ₁	5,99	*	Problem-solving/Spatial battery

* Significant at 1% level

$$r^2 = 0,41$$

2. Using the Problem-solving/spatial battery, Spargo science test, Matriculation mathematics and Matriculation aggregate as independent variables,

$$y = 33,9 + 0,36x_1 + 0,39x_2 + 0,68x_3 + 0,87x_4$$

	T Statistic		
b ₁	5,21	*	Problem-solving/Spatial battery
b ₂	1,35		Spargo science test
b ₃	0,57		Matriculation mathematics
b ₄	0,57		Matriculation aggregate

* Significant at 1% level

$$r^2 = 0,44$$

A P P E N D I X 2

2.6 - POPULATION 2

DET STUDENTS - 1984 REGRESSION EQUATIONS

JUNE 1984

1. Using only the Glasgow spatial battery score as the independent variable,

$$y = -7,91 + 3,87x_1$$

<u>T Statistic</u>		
b ₁	3,87 *	Glasgow spatial battery

* Significant at 5% level

$$r^2 = 0,695$$

2. Using the Glasgow spatial battery score, Spargo science test, Matriculation mathematics and Matriculation aggregate as independent variables,

$$y = -19,78 + 1,43x_1 + 0,15x_2 + 1,65x_3 - 0,17x_4$$

<u>T Statistic</u>		
b ₁	3,32 *	Glasgow spatial battery
b ₂	0,10	Spargo science test
b ₃	0,24	Matriculation mathematics
b ₄	-0,02	Matriculation aggregate

* Significant at 0,05 level

$$r^2 = 0,698$$

A P P E N D I X 2

2.7 - POPULATION 2

DET STUDENTS - 1984 REGRESSION EQUATIONS

NOVEMBER 1984

1. Using only the Glasgow spatial battery score as the independent variables,

$$y = 19,06 + 0,8x_1$$

<u>T Statistic</u>		
b ₁	2,57	* Glasgow spatial battery

* Significant at 5% level

$$r^2 = 0,45$$

2. Using the Glasgow spatial battery, Spargo science test, Matriculation mathematics and Matriculation aggregate as independent variables,

$$y = -15,7 + x_1 - 0,6x_2 + 0,09x_3 + 0,38x_4$$

<u>T Statistic</u>		
b ₁	1,94	Glasgow spatial battery
b ₂	-0,7	Spargo science test
b ₃	0,23	Matriculation mathematics
b ₄	0,9	Matriculation aggregate

To be significant at 10% level, T statistic 2,0

$$r^2 = 0,69$$

A P P E N D I X 2

2.8 - POPULATION 2

DIA STUDENTS - 1984 REGRESSION EQUATIONS

JUNE 1984

1. Using only the Glasgow spatial battery score as the independent variable,

$$y = -54,07 + 2,3 x_1$$

	<u>T - Statistic</u>	
b ₁	3,57	* Glasgow spatial battery

* Significant at 5% level

$$r^2 = 0,704$$

2. Using the Glasgow spatial battery score, Spargo science test, Matriculation mathematics and Matriculation aggregate as independent variables,

$$y = 7,73 + 1,15x_1 + 0,1x_2 - 0,2x_3 + 0,3x_4$$

	<u>T - Statistic</u>	
b ₁	2,3	* Glasgow spatial battery
b ₂	0,08	Spargo science test
b ₃	-0,35	Matriculation mathematics
b ₄	0,40	Matricultion aggregate

* Significant at 5% level

$$r^2 = 0,73$$

A P P E N D I X 2

2.9 - POPULATION 2

DIA STUDENTS - 1984 REGRESSION EQUATIONS

NOVEMBER 1984

1. Using only the Glasgow spatial battery score as the independent variable,

$$y = 15 + 0,94x_1$$

<u>T Statistic</u>			
b ₁	4,29	*	Glasgow spatial battery

* Significant at 5% level

$$r^2 = 0,61$$

2. Using the Glasgow spatial battery score, Spargo science test, Matriculation mathematics and Matriculation aggregate as independent variables,

$$y = -1,9 + 0,9x_1 - 0,4x_2 - 0,3x_3 + 0,7x_4$$

<u>T Statistic</u>			
b ₁	3,34	*	Glasgow spatial battery
b ₂	-0,58		Spargo science test
b ₃	-0,79		Matriculation mathematics
b ₄	1,87		Matriculation aggregate

* Significant at 5% level

$$r^2 = 0,72$$

A P P E N D I X 2

2.10 - POPULATION 2

ED STUDENTS - 1984 REGRESSION EQUATIONS

JUNE 1984

1. Using only the Glasgow spatial battery score as independent variable,

$$y = 15,25 + 1,09x_1$$

	T	Statistic	
b ₁	7,41	*	Glasgow spatial battery

* Significant at 5% level

$$r^2 = 0,487$$

2. Using the Glasgow spatial battery, Spargo physical science test, Matriculation mathematics and Matriculation aggregate as independent variables,

$$y = 14,6 + 1,0x_1 + 0,28x_2 + 0,54x_3 - 0,73x_4$$

	T	Statistic	
b ₁	6,75	*	Glasgow spatial battery
b ₂	1,22		Spargo science test
b ₃	0,55		Matriculation mathematics
b ₄	-0,62		Matriculation aggregate

* Significant at 5% level

$$r^2 = 0,496$$

A P P E N D I X 2

2.11 - POPULATION 2

ED STUDENTS - 1984 REGRESSION EQUATIONS

NOVEMBER 1984

1. Using only the Glasgow spatial battery score as independent variable,

$$y = 20,51 + 0,86x_1$$

	<u>T Statistic</u>		
b ₁	8,29	*	Glasgow spatial battery

* Significant at 5% level

$$r^2 = 0,52$$

2. Using the Glasgow spatial battery and Matriculation mathematics as independent variables,

$$y = 13,8 + 0,83x_1 + 0,13x_2$$

	<u>T Statistic</u>		
b ₁	7,97	*	Glasgow spatial battery
b ₂	2,27	*	Matriculation mathematics

* Significant at 5% level

$$r^2 = 0,54$$

3. Using the Glasgow spatial battery, Matriculation mathematics and Matriculation aggregate as independent variables,

$$y = 15,4 + 0,8x_1 + 0,1x_2 - 0,05 x_3$$

	<u>T - Statistic</u>		
b ₁	7,97	*	Glasgow spatial battery
b ₂	2,25	*	Matriculation mathematics
b ₃	-0,6		Matriculation aggregate

* Significant at 5% level

$$r^2 = 0,54$$